THE UNCERTAIN PROMISE OF AGRICULTURE:
TWO ESSAYS ON CLIMATE CHANGE, AGRICULTURE AND NUTRITION IN THE ANDEAN HIGHLANDS OF PERU

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Mary Katherine Wheeler

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ABSTRACT

Agriculture is regarded as a key driver of economic and nutritional outcomes for poor households in developing countries. Yet climate change threatens to undermine the assurance that advances in agriculture can improve the welfare of millions living in poverty. This thesis explores the uncertain promise of agriculture for farmers in the Andean highlands of Peru. It presents two papers that analyze household survey data from agricultural communities near the city of Hunacayo, within the Shullcas River Watershed, to elucidate relationships between climate change, agriculture and nutrition. The first paper evaluates factors expected to influence climate perceptions and adaptive behavior. It finds that farmers universally perceive long-term changes in climate, and overwhelmingly report negative impacts on crop production, yet the rate of explicit agricultural adaptation in response to these observations is low (15%). However, most households do report using one or more production practices that are considered by researchers to be climate adaptive. Multivariate regression results indicate that education and agricultural information provide an essential foundation for farmer adaptation, but limited access to productive resources constrains adaptive capacity. The second paper identifies a positive relationship between farm size and household dietary diversity, and it assesses two potential pathways linking agriculture and nutrition. The analysis offers strong evidence of a direct production-consumption pathway for subsistence and commercial farming households, in addition to weak evidence of an agricultural income pathway only for households with commercial crop sales. Results further suggest that off-farm income is a critical driver of food security and dietary quality in the study area. Overall, both papers support the notion that investments in agriculture may not be sufficient to reduce the welfare gap for households facing hard constraints to climate adaptation or farm profitability. Development organizations and policymakers should expect tradeoffs between efficiency and equity in the targeting of climate adaptation and nutrition-sensitive agricultural policies and programs.

BIOGRAPHICAL SKETCH

Mary Kate Wheeler is a native of Ithaca, New York. She earned her B.A. with a double major in Environmental Studies and Architecture and Urban Studies from Bowdoin College in 2007. After completing her undergraduate degree, she worked on projects related to environmental education, youth development and sustainable food systems in the U.S. and in Latin America. She also worked as a farmer and entrepreneur for several seasons in Spokane, Washington, where she launched a small diversified vegetable farm. She is glad to be back in her hometown, where she enjoys creative carpentry projects, cooking for friends and spending time out in the woods and on the water.

To people who dedicate themselves to working the land and feeding others.

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CHAPTER 1

INTRODUCTION

Agriculture occupies a unique position as the primary livelihood for a majority of the world's poor, and as a foundation for rural economies in developing countries worldwide. On the one hand, agriculture is regarded as a key driver of development, a sector in which thoughtful investment has potential to dramatically improve economic well-being and nutritional outcomes of the poor (Fan and Pandya-Lorch, 2012). Yet agriculture is also projected to be the sector most directly and severely impacted by long-term changes in temperature and precipitation (Smit and Pilifosova, 2001). As a result, climate change threatens to undermine the assurance that agricultural advances can improve welfare and enhance food security for millions of households living in poverty (Nelson et al., 2009; Lloyd et al., 2011; Phalkey et al., 2015). This thesis explores the opportunities and limitations of agriculture as means to enhance the nutrition, food security and economic well-being of farm households in the Andean highlands of Peru, a region that is particularly sensitive to climate change.

Over the past decade, Peru has made impressive advances in reducing infant and young child malnutrition at the national level. Researchers have attributed this achievement in part to strong, coordinated advocacy by civil society members of Peru's Child Malnutrition Initiative (Acosta and Haddad, 2014). However, rates of poverty and malnutrition remain high in rural areas, where a majority of people depends upon agricultural livelihoods. In 2014, almost half of Peru's rural population lived below the poverty line, and stunting affected almost a quarter of all children under five years of age in Peru's Andean highlands (INEI, 2014; INEI, 2015). Evidence that early childhood malnutrition has long-term consequences for individual educational and economic outcomes makes infant and young child nutrition a top priority on Peru's development agenda (Hoddinott et al., 2008; Maluccio et al., 2009).

The Sustainable Development Goals (SDGs), adopted by the United Nations in 2015, highlight the importance of pro-poor agricultural development as an essential step toward eliminating hunger, enhancing food security and improving nutrition, particularly for women, indigenous peoples and family farmers across the globe (United Nations, 2015). The 2030 Agenda for Sustainable Development calls for international cooperation to increase the rate of investment in rural infrastructure, agricultural research, extension services and technology innovation in order to double the agricultural productivity and incomes of small-scale food producers in developing countries. The agreement also calls for the widespread implementation of sustainable and resilient production practices that boost productivity and improve soil quality while moderating the negative effects of climate change and extreme weather events. These goals are highly relevant to the Peruvian context, particularly in the Andean region, which is characterized by high rates of rural poverty and malnutrition in areas where families depend on agricultural livelihoods to achieve food, nutrition and income security.

The SDGs present a bold vision for integrated development, yet implementation remains a challenge. Despite wide recognition of the many linkages across climate change, agriculture and nutrition, actors from these three sectors rarely work together to advance shared goals (Hoddinott, 2012). When pro-development activities and programs in the agriculture and health sectors operate separately, opportunities to develop synergistic programs and policies are likely to be overlooked. Against this backdrop, academic institutions have both the capacity and the responsibility to accelerate sustainable development processes by generating and disseminating knowledge about the political dimensions of linking agriculture and health (Jha et al., 2016). Academic actors can also give voice to civil society and promote collaboration between government agencies and nongovernmental organizations (NGOs) to develop intersectoral policies and programs. Recognizing this knowledge gap, this thesis aims to identify relationships between climate change, agriculture and nutrition in the Andean Highlands of Peru in order to highlight critical linkages that may present opportunities for cross-sectoral collaboration. The ultimate goal of this work is to inform integrated policy and programming strategies among donors, governmental agencies and non-governmental organizations that can capitalize on the linkages between the natural environment, agriculture and nutrition, and thereby improve the food security and nutritional impacts of agricultural and climate adaptation interventions.

This thesis is one outcome of a research collaboration between Cornell University and CARE Perú, a Peruvian NGO and affiliate member of CARE International, with a broad sustainable development and poverty reduction mission. With more than 50 years of experience working in Peru, CARE has a history of working with poor and vulnerable groups and delivering programming on a range of priorities, including education, economic development, climate adaptation, gender equality and nutrition (CARE, 2016). Some CARE projects focus on sustainable, resilient and climate-adaptive agriculture in the Andean highlands, while others address food security and nutrition in the same region. However, efforts to link agriculture, climate change and food security programming are just beginning. With this outcome in mind, we collaborated with development practitioners from CARE Perú to develop the research questions that informed the overall analytical approach, methods and findings described in this thesis. Specifically, this research aims to (1) evaluate factors that influence farmer perceptions of climate change and their uptake of adaptive responses, and (2) identify relationships and evaluate pathways linking agriculture and nutrition.

The chapters that follow present two papers that analyze survey data gathered from 286 farming households in the Shullcas River watershed, a sub-basin of the greater Mantaro River Valley situated in the Cordillera Blanca of Central Peru. The geographical features of the research area are described in detail in Chapters 2 and 3. The Mantaro River Valley is considered to be a breadbasket of Peru due to extensive production of potato, maize and a cornucopia of other grains, tubers, legumes and vegetables. The Shullcas River links the tropical Huaytapallana glacier with the Mantaro River and the large Andean city of Huancayo, where it provides the city's primary source of drinking water. Yet the Shullcas River also serves as the main source of irrigation water in many surrounding agricultural communities. This watershed is considered to be a zone of extreme vulnerability to climate change risks and impacts, especially given the area's dependence on glacial meltwater. Temperatures are rising faster in the Andean highlands than in the surrounding lowlands. Increases in the frequency, intensity and unpredictability of extreme weather events, including floods, droughts and frosts, are expected to magnify production risks and reduce agricultural yields. The rapid retreat of the Huaytapallana glacier, which may disappear within the next 15 years, is projected to cause water shortages that may lead to social conflict (López-Moreno et al., 2014). Thus, long-term changes in climate represent a significant threat to the sustainability and productivity of agriculture in the Shullcas River watershed and the broader Andean region.

By threatening crop yields, climate change is projected to negate progress toward the development goals that would otherwise be accomplished in the coming decades. One study warns that, without aggressive investments in agriculture to offset climate impacts, the global prevalence of child malnutrition will rise 20% by 2050 relative to a world without climate change (Nelson et al., 2009). This trend is particularly concerning for Peru's Andean highlands, a region characterized by extreme climate vulnerability and relatively slow progress toward reducing malnutrition. Yet the potential for climate adaptation to moderate damages and exploit new opportunities, in Peru as elsewhere, is high (Smit and Pilifosova, 2001). The research reported in Chapter 2 seeks, first, to understand the factors that influence climate perceptions of farm households, and second, to analyze the factors that influence climate adaptive behaviors of those households. Analytical attention is given to four specific climate adaptive responses: (1) growing native potato varieties; (2) planting trees; (3) using irrigation systems; and (4) adopting soil and water conservation practices. Understanding these factors and how they operate at the farm level is an important step toward developing climate policy at the local and national levels (Lee et al., 2015). By evaluating the factors that influence farmer perceptions of climate change and their uptake of adaptive responses, Chapter 2 addresses a critical knowledge gap regarding climate perceptions and adaptations among farming households in the Andean highlands.

While Chapter 2 addresses the potential of adaptation to counteract the uncertainty of climate change, Chapter 3 explores the promise of agriculture to improve food security and dietary quality for Andean agriculturalists, particularly among the poorest households. Nutrition-sensitive agriculture has emerged within the past few years as a promising filed for research and policy development (Fan and Pandya-Lorch, 2012). However, the specific pathways linking agricultural production to nutritional outcomes at the household level are often ambiguous, given the complexity of farming systems and the linkages among farm production outcomes, household labor arrangements, non-farm livelihood activities, off-farm income sources, and household expenditure patterns. Thus, a deeper understanding of the specific pathways linking agricultural production to household food consumption and food security outcomes is critical for designing nutrition-sensitive policies and interventions. Chapter 3 addresses the complexity of this question by evaluating the relative importance of two possible pathways linking agriculture and the nutritional quality of household diets − a household income pathway and a direct food production-consumption pathway − for farming operations that sell some of their products in the market versus those that produce solely for home consumption.

Chapter 4 concludes with a synthesis of major findings from the two papers, and a discussion of relevant policy implications.

CHAPTER 2

FARMER PERCEPTIONS OF CLIMATE CHANGE AND ADAPTIVE RESPONSES

2.1 INTRODUCTION

Global climatology models widely project rising temperatures, changing precipitation patterns and a greater frequency of extreme weather events, including droughts and floods. Food production is especially vulnerable to climate change, as agricultural systems are inherently sensitive to climate conditions. Climate change impacts on agriculture and food security are particularly concerning for developing countries, where a majority of the world's poor depend upon agricultural livelihoods to achieve income and food security. While production systems in developing countries have historically responded to variable climate and weather conditions, the increasing rate and scale of climate change impacts may exceed their adaptive capacity (IPCC, 2001).

Changes in global climate patterns create new threats and opportunities for regional and local food systems. The resulting impacts on agriculture depend in large part upon the ways in which interconnected social, economic and ecological systems adjust in response to climate changes and their impacts. Indeed, climate research stresses adaptation as a key policy concern, with significant potential to reduce the vulnerability of agricultural systems (Rosenzweig and Parry, 1994; Smith and Lenhart, 1996; Smit and Skinner, 2002). Given that many smallholder farmers have limited access to information and other social, financial and natural resources, there exists a critical need to build adaptive capacity at the farm and village levels to reduce vulnerability and moderate climate impacts, particularly in less-developed regions. Since most adaptive farm management and resource allocation decisions are undertaken at the micro level, understanding the perceptions and behavioral responses of individual farmers and households is critical to developing regional and national climate policies (Gbetibouo, 2009; Lee et al., 2014).

Food production throughout South America's Andean region is critically vulnerable to climate change, and the impacts are already being felt by farmers in the Peruvian highlands (Lee et al., 2014). Peru is a country highly affected by climate change, and it boasts seven of the nine vulnerability factors set forth in the 1992 United Nations Framework Convention on Climate Change, including exposure to floods, droughts and desertification; the presence of zones prone to natural disasters; and fragile mountain ecosystems (USAID, 2012). Peru's economy is highly dependent on agriculture, which is the sector projected to be most directly and severely impacted by long-term changes in temperature and precipitation (de la Torre, 2009). Smallholder farming households in the Andean highlands are expected to be among Peru's most sensitive population groups due to the relative intensity of projected climate impacts at higher elevations, compounded by the low adaptive capacity of a dispersed rural population characterized by high rates of poverty and limited access to basic health and human services (UNDP and BCPR, 2013).

Against the backdrop of growing uncertainty and risk for farmers in Peru, agricultural adaptation offers farming households a chance to reduce vulnerability and moderate climate impacts by responding strategically to actual and expected changes. Recent studies that examine producer adaptations in Andean farming systems emphasize the role of indigenous knowledge (Vivaldia et al., 2010; Boillat and Berkes, 2013), mobility and migration (Ho and Milan, 2012), and ecosystem governance (Lennox and Gowdy, 2014) as key components of adaptation. McDowell and Hess (2012) show that multiple livelihood stressors, not just climate, inform climate-adaptive management practices in the Bolivian highlands. Broader econometric studies emphasize crop and livestock selection as key adaptive management strategies, and predict changes in crop and livestock composition across the South American continent in response to climate stimuli (Seo and Mendelsohn, 2008; Seo et al., 2010). However, econometric analysis of the factors that potentially influence climate perceptions and adaptations specifically within the Andean region is lacking. Our study addresses this gap.

Outside of the Andean region, many empirical studies use a technology adoption framework to evaluate farmer perceptions of climate change and the behavioral process by which farmers implement adaptation strategies (Smit and Skinner, 2002). This literature helps to explain the relationship between farmer perceptions and actions, on the one hand, and, on the other, provides an analytical context for estimating the likelihood of adaptation conditional on biophysical and socioeconomic characteristics of the farm and household. Researchers have applied this approach to many different settings within the African continent (summarized by Juana et al., 2013), and, more recently, to the Middle Eastern (Abid et al., 2015) and Latin American (Roco et al., 2015; Useche and Anglade, 2015) regions. However, we know of no study that applies this framework to evaluate climate perceptions and adaptations exclusively in Andean farming systems.

Our study builds on this literature in order to investigate the factors contributing to climate change perceptions and agricultural adaptations among farmers in the Cordillera Blanca of Central Peru. Using survey data from 286 farm households across six villages in the Shullcas River watershed, our study employs multivariate linear and logistic regression analysis to explore the role of household characteristics, farm attributes and agricultural information in influencing climate perceptions and adaptive responses. Our work extends the literature on climate perceptions and adaptations among smallholder farmers to the Peruvian Andes, an understudied yet critically vulnerable region.

The paper is organized as follows. The next section provides additional background information on climate change and adaptation in the Peruvian highlands. Section 2.3 describes the study site and data, while Section 2.4 outlines the conceptual framework and empirical estimation strategy. We report results in Section 2.5, and Section 2.6 concludes the chapter.

2.2 CLIMATE CHANGE AND ADAPTATION IN THE PERUVIAN ANDES

Despite high intra-annual climate variation in Peru, numerous studies have recorded meaningful deviations from historical climate trends (SENAMHI, 2009; IGP, 2010; Trebejo and Avalos, 2011; UNDP and BCPR, 2013). Over the past 40 years Peru has experienced rising temperatures at a rate of 0.2°C per decade, yet the warming rate is greater at higher elevations. One study suggests that temperatures will rise two or more times faster in the Andean highlands compared to trends at lower elevations (Bradley et al., 2006). Although warmer temperatures may improve growing conditions and potential yields for some Andean crops, they are expected to magnify the risk of crop failure for rainfed production systems in the central Peruvian Andes (SENAMHI, 2013; Sanabria et al., 2014). Warmer temperatures also increase evapotranspiration rates and amplify the spread and intensity of crop pests and diseases (IGP, 2010; Perez et al., 2010). Yet the most severe climate impacts and risks for farmers in the Peruvian highlands are expected to come not from rising temperatures but from associated changes in precipitation patterns, water availability, and the frequency and timing of frost events.

Although the volume of precipitation throughout most of the Peruvian highlands has not changed significantly since the 1960's (SENAMHI, 2009), evidence suggests that the frequency, intensity, duration and uncertainty of extreme weather events, specifically droughts, rains and frosts, have increased over the same period (USAID, 2011; USAID, 2012). This trend is projected to continue, and it is likely to reduce soil moisture and groundwater reserves while increasing soil erosion (Perez et al., 2010). In the Mantaro River Valley of the central Peruvian Andes, researchers have documented an increasing frequency of *veranillos,* or "little summers", defined as brief but intense droughts occurring during the rainy season and lasting at least 10 days, with no more than 1 mm of rainfall per day (UNDP and BCPR, 2013). Such events have major consequences for crop yields in rainfed agricultural systems, particularly when they occur during the peak rainy season (Trebejo and Avalos, 2011).

The rapid retreat of tropical glaciers is expected to compound problems associated with increasing variability in precipitation throughout the region, including water shortages. Peru is home to more than 70% of the world's tropical glaciers, which are the primary source of freshwater for the country's population of more than 30 million people (USAID, 2011; USAID, 2012). Since 1980, the total surface area covered by glaciers in Peru has decreased by 22%, or roughly 20 meters per year, although some individual glaciers are retreating even more rapidly (Vargas, 2009; IGP, 2010). Many of Peru's glaciers are projected to disappear within the next two decades, particularly those that are smaller in size or situated at lower elevations (Ramírez et al., 2001; Bradley et al., 2006). Glacial retreat poses serious threats to water supplies for both urban and rural populations in the Andes (Bradley et al., 2006). Conflicts over water resources among Peru's residential, agricultural and industrial stakeholders have already been documented, and they are expected to increase in both frequency and volatility in the years to come (Gelles, 2000; USDA, 2012).

Climate models for the Andean highlands predict rising mean and maximum temperatures, but some also predict greater variation between daily highs and lows. In fact, minimum temperatures have decreased in some regions, including in the Mantaro River Valley (Trebejo and Avalos, 2011). Consequently, frost events are becoming more frequent in some parts of the Peruvian highlands, and their timing is increasingly erratic (Perez et al., 2010; UNDP and BCPR, 2013). Frost is a limiting factor for crop production in the Andean highlands, and unseasonable frost events can have dire consequences for crop yields, livestock mortality and the food security of Andean households (USAID, 2011).

Adaptation is therefore a critical concern for Andean farmers and the institutions that support them. As early as 2003, Peru developed a National Climate Change Strategy to advance policies and actions that could build the country's adaptive capacity. In 2007 the Regional Government of Junín, within which our study site is located, became the first to formulate its own Regional Climate Change Strategy. Government agencies including the National Meteorology and Hydrology Service (SENAMHI), the Ministry of Agriculture and Irrigation

(MINAGRI) and the Ministry of the Environment (MINAM) have led efforts to research and develop climate models, long-term weather forecasts and climate adaptive measures (SENAMHI, 2009; IGP 2010; USAID, 2011; SENAMHI, 2013). National and international development agencies have supported and extended these efforts, with a particular emphasis on understanding and enhancing adaptive capacity for agriculture and water resource management (USAID, 2011; Ho and Milan, 2012; USAID, 2012; UNDP and BCRP, 2013). Despite these accomplishments, relatively little is known regarding household-level attitudes and perceptions about climate change, or the factors that influence the adaptive capacity of agricultural households in Andean farming systems. Yet, input from this population is critical for successful climate policy development and regional adaptation planning (Lee et al., 2009). Consequently, our study adopts a bottom-up approach, which "seeks to gain insights from the farmers themselves" in order to enrich our understanding of the risks, opportunities, resources and constraints that shape their choices and outcomes (Gbetibouo, 2009).

2.3 STUDY SITE AND DATA COLLECTION

2.3.1 Description of the study area

Our study area is defined by the boundaries of the Schullcas River watershed, a sub-basin of the Mantaro River Valley, located within Junín Region in the central Peruvian Andes (Figure 2.1). The Shullcas River extends from the Huaytapallana glacier (4,800 m) to the Mantaro River (3,200 m) and drains an area of over 23,000 hectares (Concha Flores, 2011; SENAMHI 2013). Fed by glacial melt and rainfall, the Shullcas River serves as the main water source for both urban and agricultural uses throughout its drainage basin. The greater Mantaro River Valley is characterized by a tropical, high-elevation climate. The region has a mean annual temperature around 10°C, and mean annual rainfall of approximately 740 mm, although it experiences significant variation in annual rainfall between wet (900 mm/year) and dry (400 - 500 mm/year) years (IGP, 2005). Temperature follows a diurnal cycle, such that daily variation is greater than seasonal variation. In contrast, precipitation follows a seasonal cycle in which 83% of rainfall occurs between October and April.

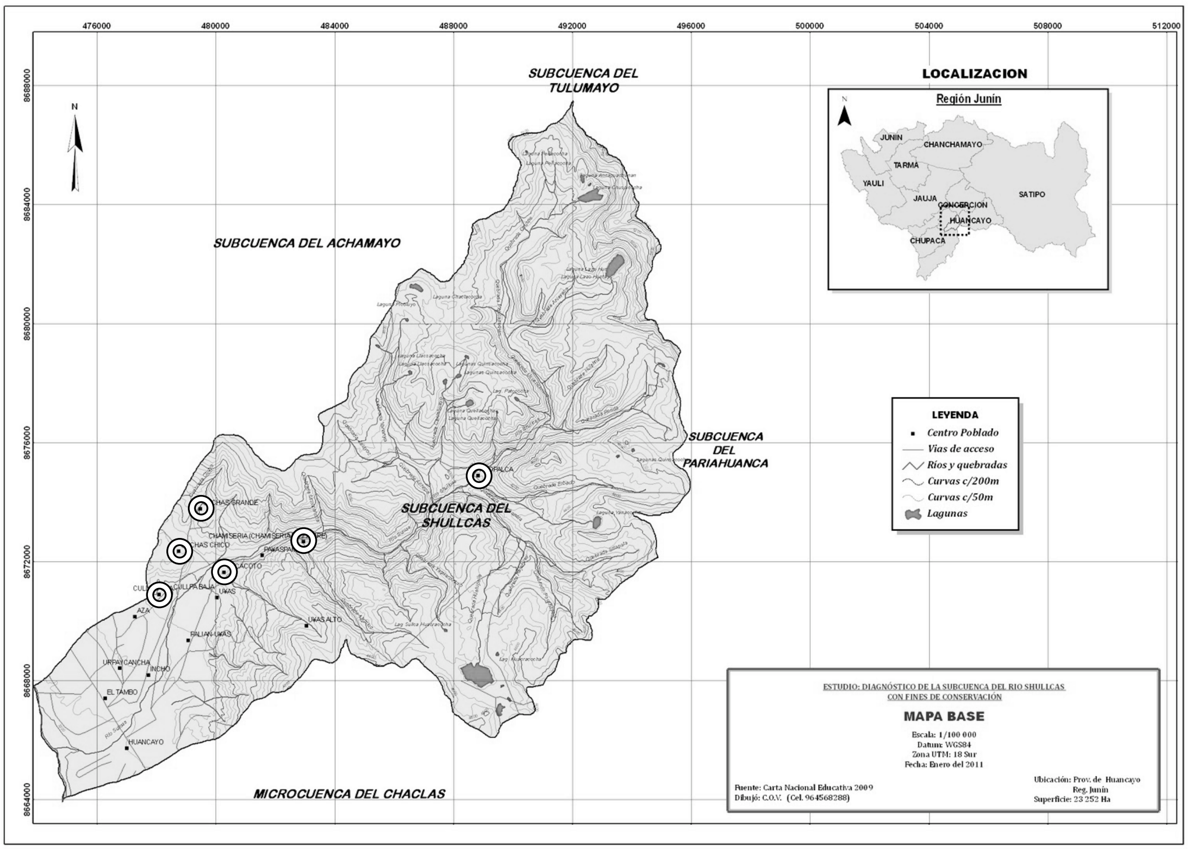

Figure 2.1. Map of the Shullcas River Watershed. The Shullcas River extends from the Huaytapallana glacier along the northeast edge of the watershed to the city of Huancayo and the Mantaro River in the southwest. White circles indicate the locations of the six study villages. The map is adapted from Mapas Temáticos del Peru: http://mapasplanosperu.blogspot.com/2011/02/mapa-de-vegetacion-de-la-subcuenca-del.html

Economic activity along the Shullcas River is clustered around the municipality of Huancayo, a growing urban center with a population of almost half a million. The Shullcas River watershed spans two of Huancayo's seven districts, encompassing just over 278,000 inhabitants (Haller and Borsdorf, 2013; INEI, 2013). In smaller villages outside the urban zone, many families rely on traditional agricultural practices to meet subsistence needs. Farmers commonly grow maize, broad bean and modern potato varieties in the lower elevation *quechua* zone (< 3,500 m) where plots tend to be flatter and more fertile, and where irrigation is possible. Plots tend to be steeper, and typically lack irrigation, in the middle elevation *suni* zone (3,500 - 3,800 m), where farmers tend to plant hardier native tuber crops, including *oca*, *olluco*, *mashua* and numerous varieties of native potato. Wheat, barley and quinoa are also grown in the region. Due to climate extremes, farming households rarely produce crops in the *puna* (> 3,800 m), but they often pasture livestock in this higher elevation agroecological zone. Most of the farmers in this region produce crops for home consumption and sell little or none of their harvest in the market. Indeed, the vast majority of households in our study (86%) rely on off-farm activities to generate income.

The Andean region is recognized as one of the most vulnerable areas to climate change worldwide, and farmers in the Mantaro River Valley are already experiencing some of the changes predicted by climate models (Lee et al., 2009; UNDP and BCRP, 2013). Within this region, the Shullcas River sub-basin is considered a zone of particularly high vulnerability. Meltwater from the Huaytapallana glacier is critical to maintaining water levels in the Shullcas River, yet if the glacier continues retreating at its current rate it is projected to disappear within the next fifteen years (López-Moreno et al., 2014). Due to concerns about future water shortages and related social conflict, this watershed has received increasing attention from government agencies and international development organizations (CARE, 2012; Ho and Milan, 2012). However, local populations lack broad access to meteorological data and associated information about climate risks and consequences (CARE, 2011). Moreover, poor social and economic conditions exacerbate climate vulnerabilities and pose additional development challenges. Despite Peru's impressive economic growth over the past ten years, rates of poverty and malnutrition remain high in Junín Region, particularly in the rural areas (INEI, 2013).

2.3.2 Sampling and data collection

CARE Perú and Cornell University collected the data used in this analysis as part of a larger study on agriculture, food security and nutrition. Eight trained enumerators conducted integrated household production and consumption surveys in six villages between September and early December 2015. The villages varied in size, population, elevation, and distance to major markets in the city of Huancayo (Table 2.1). They were chosen because they were the most heavily engaged in agriculture within the Shullcas River Watershed. The survey targeted households that grew field crops in the prior farming season, between September 2014 and September 2015. A total of 286 farming households completed the survey; Table 2.1 reports their distribution across the six villages. The sample included a majority of farming households in each village, and, to the best of our knowledge, was highly representative of agricultural households from the six-village sample. The survey recorded detailed information about household agricultural production, food consumption, and indicators of socioeconomic status. In addition, a subset of 240 households that had lived in their current village for ten years or more responded to a set of question on about their perceptions of long-term climate change, which used the prior 10 years as the reference period.

Table 2.1

Village Attributes and Survey Participation

Village	Elevation	Distance to Huancayo	2007 Population	2015 Survey Participants
	masl	km	households	households
Acopalca	3,898	18.0	192	35 (33)
Chamisería	3,584	10.5	-	13 (11)
Vilcacoto	3,443	7.5	169	30 (25)
Cochas Grande	3,622	9.8	172	39 (33)
Cochas Chico	3,490	9.0	503	100 (81)
Cullpa Alta	3,365	6.6	287	69 (57)
Total			1,323	286 (240)

Note. Population estimates come from the Instituto Nacional de Estadística e Informática (INEI, 2007). The 2007 population estimate for Acopalca includes residents of Chamisería. The numbers in parentheses indicate the sub-sample of households in that completed the survey module on perceptions of climate change.

2.4 CONCEPTUAL FRAMEWORK & EMPIRICAL SPECIFICATION

2.4.1 Modeling climate perceptions

Recent empirical studies highlight the importance of agroecological and socioeconomic factors, including access to information about agriculture and climate, in shaping farmer perceptions of climate change and the resulting impacts on production (Deressa, 2011; Ndambiri et al., 2012; Silvestri et al., 2012; Debela et al., 2015; Roco et al., 2015). We therefore model perceived climate impacts as a function of household characteristics, farm attributes and agricultural information sources. We also include village effects, which capture a considerable portion of the agroecological variation in our study area.

Consider a sample of N agricultural households indexed by $i = 1, \ldots, N$, from $j = 1, \ldots, J$

villages. We model the perceived climate impacts held by the primary farmer of household i in village j, denoted by Ω_{ij}, as a function of four vectors (subscripts suppressed for simplicity):

$$\Omega = f(\boldsymbol{X}, \boldsymbol{F}, \boldsymbol{I}, \boldsymbol{V}) \quad (1)$$

The vector of explanatory variables, $\boldsymbol{X}$, denotes a set of household socioeconomic and demographic covariates that may affect a household's experience of climate events, as well as its ability to interpret relevant information and update beliefs. The second vector, $\boldsymbol{F}$, is comprised of farm attributes that may be differentially resistant or vulnerable to impacts of climate change. The third vector, $\boldsymbol{I}$, represents different sources of information about agriculture, which are expected to shape farmer attitudes and perceptions. Finally, $\boldsymbol{V}$ is a vector of village indicators that we include to control for heterogeneity in elevation, temperature, rainfall, slope, distance to urban markets and other village-level characteristics that might affect climate perceptions. In our study area, villages further from the urban center of Huancayo are higher in elevation, have steeper sloping land, and typically experience colder and wetter weather. Thus, village of residence is consistently associated with village-level variations in a variety of socioeconomic variables and agroecological conditions.

Researchers often model household-level climate perceptions using a binomial logit or probit model with a binary outcome variable that represents whether or not the primary farmer reports observing changes in climate over a specified time period (Dressa et al., 2011; Ndambiri et al., 2012; Okonya et al., 2013). This approach works well for contexts in which some farmers perceive climate change while others do not. In our sample, *every household* that had lived for at least ten years in its current village reported observing multiple changes in climate over the past decade. For this reason, our data lack the heterogeneity necessary to model perceptions of climate change as a single binary "yes or no" outcome.

However, farmer perceptions of individual climate changes and the resulting impacts on food production did vary considerably across our sample. We exploit this heterogeneity by constructing a Climate Impact Score (CIS) that aggregates reported ranked impacts of 12 different climatic changes reported by the households in our sample. A higher value indicates a greater extent of perceived damage to crop production, in terms of both the number of impacts and their relative magnitudes. To calculate the CIS, denoted by Ω_i for household $i = 1, \ldots, N$, we sum the product of a perception variable p_{ic} multiplied by an impact rank, r_{ic}, for each reported climate change indexed by $c = 1, \ldots, 12$ (Equation 1). The perception variable equals 1 if farmer i observed change c, otherwise 0. The impact rank r_{ic} expresses the extent to which climate change c impacted farmer i's crop production. We code r_{ic} as 1 = low impact; 2 = moderate impact; 3 = large impact. This approach assumes that any climate change that the household observed could potentially impact its production, but that if household *i* did not observe change *c*, then *c* could not impact *i*'s production.

$$\Omega_i = \sum_{c=1}^{12} p_{ic}\, r_{ic} \tag{2}$$

Assuming a linear functional form, we can express climate perceptions as a linear combination of the vectors ***X***, ***F***, ***I*** and ***V***, each multiplied by a vector of population parameters β_1, β_2, β_3 and β_4, and an idiosyncratic term ε containing all other factors that explain variation in Ω.

$$\Omega = \boldsymbol{X}'\beta_1 + \boldsymbol{F}'\beta_2 + \boldsymbol{I}'\beta_3 + \boldsymbol{V}'\beta_4 + \varepsilon \tag{3}$$

We take ε to be an i.i.d. random variable with an expected value conditional on the regressors expressed as $E(\varepsilon|_{X,N}) = 0$. Therefore:

$$E(\Omega) = \boldsymbol{X}'\beta_1 + \boldsymbol{F}'\beta_2 + \boldsymbol{I}'\beta_3 + \boldsymbol{V}'\beta_4 \tag{4}$$

We use ordinary least squares (OLS) to estimate the parameters of this multivariate linear regression model.

2.4.2 Modeling climate adaptations

Numerous definitions of adaptation exist within the climate change literature (Smit et al., 2000). It therefore seems worthwhile to clarify how empirical researchers typically define the concept before discussing our approach to modeling it. Empirical studies that examine agricultural adaptation to climate change tend to frame climate adaptation in one of two different ways. The first approach focuses on *conscious adaptation strategies*, that is, changes in production patterns that farmers adopt intentionally in response to perceived climate opportunities, threats or impacts. This conceptual framework aligns with a common definition of adaptation in human systems as a "process of adjustment to actual or expected climate and its effects […] to moderate or avoid harm, or exploit beneficial opportunities" (IPCC, 2014). Because this framework emphasizes *intent*, farmer perceptions of climate change are considered to be a necessary precursor to agricultural adaptation (Deressa et al., 2011; Abid et al., 2015). Researchers that use this definition rely on farmers to self-identify adaptation practices that they have implemented with the intention of responding to observed changes in climate.

Alternatively, some researchers extend the concept of adaptation to include all adjustments that "reduce the vulnerability of natural and human systems" (IPCC, 2007). Because this definition emphasizes the *outcome* of an action, rather than the intent, a researcher using this conceptual framework typically identifies *climate adaptive production practices* based on their potential to reduce climate vulnerability or increase adaptive capacity. This approach fosters a broader understanding of farmer behavior, and acknowledges that farmers adjust production practices in response to multiple stressors that may be related to climate change directly, indirectly or not at all (McDowell and Hess, 2012). Given that many adaptation options for agriculture offer net benefits independent of climate change (Smith and Lenhart, 1996), this framework allows for the very real possibility that a farmer could choose to adopt or maintain one or more climate adaptive farming practices without necessarily considering any of them to be motivated by climate change. Studies in this category still describe farmer perceptions of climate change, but they place less emphasis on perception as a core driver of climate adaptive behavior. This conceptual framework can be advantageous in analyzing data that include information on production practices but fail to capture farmer perceptions (Seo and Mendelsohn, 2008; Seo et al., 2010). It is also useful for evaluating adaptation strategies of particular interest to researchers and policymakers (Hassan and Nhemanchena, 2008).

There is some overlap among the empirical approaches used to model adaptation under these two distinct conceptual frameworks. Some studies in the first category use a two-stage Heckman procedure in order to control for "selection" into the subgroup of households that perceive climate change (Gbetibouo, 2009; Deressa et al., 2011; Okonya et al., 2013). This approach assumes that farmers must first perceive long-term changes in climate before they can adapt. Alternatively, multinomial logit modeling is popular when households fit neatly into multiple, non-overlapping groups based on their selected adaptation strategy (Hassan and Nhemanchena, 2008; Seo and Mendelsohn, 2008; Deressa, 2009; Seo et al., 2010). If households report implementing multiple non-exclusive adaptations, then the researcher may combine individual adaptation measures into broader categories in order to avoid overlap (Bryan, et al, 2013). For this reason, the multinomial logit model is well suited to studies that adopt the second conceptual framework in which it is the researcher, not the farmer, who identifies and defines the climate adaptations of interest. Finally, binary choice methods are commonly used in conjunction with either of the two conceptual frameworks. Researchers have applied logit or probit techniques to model the likelihood of any adaptation at all (Fosu-Mensah et al., 2012), as well as the likelihood of implementing each of several different specific adaptation practices (Silvestri et al., 2012; Abid et al., 2015).

Realistically, it is likely that conscious or explicit adaptation strategies exist simultaneously with other implicit adaptive practices within the same agricultural region, and even within an individual household's farming system. Yet we are not aware of any study that combines these two conceptual approaches in one analysis. Our survey data include detailed information on both farmer-identified conscious adaptation strategies and researcher-identified climate adaptive production practices. Initially we planned to focus on the former in our analysis. However, the extremely low rate of conscious adaptation among households in our sample (15%) suggests that a conceptual framework emphasizing intentional adaptation may not be the best fit for our data. Furthermore, when we attempted to predict variation in conscious adaptation using a binary logit model, test statistics indicated that the model was not statistically significant at a 1% confidence level (Appendix 1). Thus, we cannot not reject a null hypothesis of no impact, collectively, of the set of independent variables expected to influence conscious adaptation. For these reasons, we elect to model the likelihood of adopting four specific climate adaptive production practices, described in the following section, which are considerably more prevalent in our study area than are the conscious adaptation strategies reported in the survey.

We apply a traditional utility maximization framework to this problem. Consider latent variable U_{ij} to be the expected net benefit (utility) to farm household *i* in village *j* of adopting an adaptive farming practice. We model a farmer's expected utility from this practice as a function of household characteristics, farm attributes, agricultural information sources and village effects. Following random utility theory, we make several key assumptions.

First, U_{ij} is a random variable that varies across households in the population depending on some function $U = g(\boldsymbol{X}, \boldsymbol{F}, \boldsymbol{I}, \boldsymbol{V})$. Although U_{ij} is not observable to the researcher, it can be decomposed into a linear function of observable attributes $\boldsymbol{X}_{ij}$, $\boldsymbol{F}_{ij}$, $\boldsymbol{I}_{ij}$ and $\boldsymbol{V}_{ij}$, and unobservable attributes ε_{ij}, that are expected to influence the adaptation decision. As outlined above, $\boldsymbol{X}_{ij}$ is a vector of household characteristics (including a constant), $\boldsymbol{F}_{ij}$ is a vector of farm characteristics, $\boldsymbol{I}_{ij}$ is a vector of information sources and $\boldsymbol{V}_{ij}$ is a vector of village indicators. Parameters γ_1, γ_2, γ_3 and γ_4 are column vectors of population parameters representing the respective marginal effects of $\boldsymbol{X}$, $\boldsymbol{F}$, $\boldsymbol{I}$ and $\boldsymbol{V}$ on U (subscripts suppressed for simplicity):

$$U = \boldsymbol{X}'\gamma_1 + \boldsymbol{F}'\gamma_2 + \boldsymbol{I}'\gamma_3 + \boldsymbol{V}'\gamma_4 + \varepsilon \tag{5}$$

Second, we assume that farmers will choose to adopt a climate adaptive production practice "only if they perceive a reduction in risk or an increase in the expected net farm benefits" (Abid et al., 2015). Thus, a household will adopt if and only if its expected utility from adaptation is positive ($U > 0$).

Third, the adaptation decision is a discrete event with a "yes or no" outcome. Accordingly, the choice variable y is coded as 1 if the household chooses to adopt the production practice, and 0 if not:

$$y = \begin{cases} 1 & if\ U = \boldsymbol{X}'\gamma_1 + \boldsymbol{F}'\gamma_2 + \boldsymbol{I}'\gamma_3 + \boldsymbol{V}'\gamma_4 + \varepsilon > 0 \\ 0 & otherwise \end{cases} \tag{6}$$

Finally, we take the error term ε to be homoscedastic and logistically distributed. Given these four assumptions, we can map the utility function onto a nonlinear logit model that expresses the probability of adoption as a function of the linear combination taken from Equation 5 (Greene, 2003):

$$Pr(y = 1) = \frac{e^{\boldsymbol{X}'\gamma_1 + \boldsymbol{F}'\gamma_2 + \boldsymbol{I}'\gamma_3 + \boldsymbol{V}'\gamma_4}}{1 + e^{\boldsymbol{X}'\gamma_1 + \boldsymbol{F}'\gamma_2 + \boldsymbol{I}'\gamma_3 + \boldsymbol{V}'\gamma_4}} = \Lambda(\boldsymbol{X}'\gamma_1 + \boldsymbol{F}'\gamma_2 + \boldsymbol{I}'\gamma_3 + \boldsymbol{V}'\gamma_4) \tag{7}$$

To estimate the γ parameters we derive the log likelihood function, which expresses the log odds of the adoption decision as a linear combination of explanatory variables:

$$log[Pr(y = 1)/(1 - Pr(y = 1))] = \boldsymbol{X}'\gamma_1 + \boldsymbol{F}'\gamma_2 + \boldsymbol{I}'\gamma_3 + \boldsymbol{V}'\gamma_4 \tag{8}$$

We use maximum likelihood estimation to estimate parameter coefficients. Recall that the γ parameters give the marginal effects of the independent variables on the latent utility variable (Equation 5). We therefore calculate the marginal effect of each independent variable on $Pr(y = 1)$, following Greene (2003), to express the expected change in the likelihood of climate adaptation with respect to unit changes in each explanatory variable.

2.4.3 Climate adaptation outcome variables

Considering that farming systems in our study area are largely characterized by annual crop production, most farm-level production responses to predicted changes in temperature and precipitation can be broadly classified into three groups (Smit and Skinner, 2002). The first set of adjustments relate to the timing of planting, harvesting, or other key management activities. For example, farmers may accelerate or delay their planting date in response to variation in the arrival of seasonal rains, particularly if they lack irrigation. In fact, shorter crop cycles have been predicted, and documented, in the central Peruvian Andes (UNDP and BCPR, 2013; Sanabria et al., 2014).

A second category of adaptive farming practices pertains to crop and variety selection. Farmers may elect to grow new crops or varieties with specific, desirable traits, such as drought tolerance, frost hardiness or a shorter growing period. In Andean farming systems, the incredible biodiversity of native potato and other endemic root crops offers great potential for selecting and developing hardier varieties (Gutiérrez, 2008). Given that many varieties of native potato require less water than corresponding modern varieties and can withstand colder temperatures, variety selection is considered to be one of the most effective strategies to combat crop damage from frost and drought (Perez et al., 2010).

Soil and water management practices, including soil and water conservation, offer another set of adaptation strategies particularly well suited to address changes in the timing, amount, variability and intensity of precipitation. Irrigation can moderate the negative effects of erratic rainfall and reduce the risk of crop failure during times of drought. Swales and infiltration ditches can slow rainfall runoff and increase soil infiltration, helping to recharge local waterways and reduce the risk of flooding. Improving the efficiency of irrigation is especially applicable where climate models predict increasing likelihood of water shortages. Soil and water management are closely related, as the incorporation of crop residues, animal manure and compost into agricultural soils can boost soil organic matter, thereby enriching soil health and enhancing water infiltration and retention. Soil conservation strategies such as terracing, contour planting and hedgerows can further help to reduce soil erosion. Agroforestry practices may offer multiple economic benefits to farmers by generating products for sale, while also stabilizing soils, reducing erosion, slowing runoff, improving water infiltration, and sequestering carbon in the soil.

Based on our review of adaptive measures in Andean farming systems and the available data from our household survey, we initially identified four outcome variables representing distinct climate adaptive production practices: (1) growing native potato; (2) planting trees; (3) irrigation use; and (4) soil or water conservation. In our sample, cultivating native potato was the most widespread of these four practices (57.0%), followed by tree planting (42.0%), irrigation (35.7%), and soil or water conservation (21.0%). Each of these measures is coded as a binary choice variable such that "1" represents adoption and "0" indicates the practice is not in use. Households receive a "1" for the respective choice outcome if they grew native potato or used irrigation in the previous year. The soil or water conservation outcome aggregates a number of different individual measures that were all relatively infrequent: incorporation of manure or compost (13.3%); crop rotation (4.2%); contour planting (4.9%); polyculture systems (3.5%); terraces or barriers on contour (3.1%); infiltration or drainage ditches (3.1%); hedgerows (2.4%). For this adaptation outcome a household receives a "1" if it used one or more of these seven practices in the prior season, otherwise "0". The household survey used a three-year recall period for tree planting, so households receive a "1" if they reported planting trees within in the previous three years.

Because values for all of the explanatory variables are reported for the prior year, while the tree planting choice variable references the prior three years, the decision to plant trees may not be contemporaneous with observed household characteristics, farm attributes or information sources. We therefore assume that, for each household, the observed values of explanatory variables recorded during the study period provide an adequate proxy for the unobserved values taken by each explanatory variable in the period when the tree planting decision was made. This assumption may also be relevant for the other choice outcomes. Although the survey asked whether or not the household used irrigation in the prior year, it did not ask when the irrigation system was installed. Similarly, the survey asked whether or not the household planted native potato in the prior growing season, but it did not record the first year that the household began planting native potato. It also recorded the use of various soil and water conservation strategies in the prior season, but not the date that the household initiated those strategies. Yet, it is likely that outcomes of past adoption decisions persist over time. We therefore proceed with the assumption that the values for explanatory variables in the prior year provide an adequate proxy for the unobserved values of those same variables in the period when the adoption decision was made. This intertemporal dynamic has implications for the interpretation of estimation results, which we address in Section 2.5.

2.4.4 Explanatory variables

We select explanatory variables based on a comprehensive review of the climate adaptation and technology adoption literature (Lee, 2005; Nhemachena and Hassan, 2007; Juana et al., 2013). The same set of explanatory variables predicts variation in climate perception and in the likelihood of climate adaptation. Table 2.2 lists and describes the explanatory variables along with their expected signs.

Table 2.2

Explanatory Variables, Descriptions and Summary Statistics (N=286).

Variable	Description	%	Mean (SD)	Expected Sign
Female	1 if HH head is female; 0 otherwise	29.7		(±)
Age	Age of HH head in years		47.8 (15.1)	(+)
Age squared	Squared age of HH head		2513 (1524)	(−)
Education	Highest educational attainment of HH head in years		8.11 (4.25)	(+)
Household size	Number of individual members in the HH		4.62 (2.19)	(+)
% Members < 5 yrs	Percent of HH members less than 5 years of age		10.7 (13.6)	(−)
Wealth	Asset-based wealth index		-2.06 (8.16)	(+)
Comunero status	1 if HH is an active *comunero* member; 0 otherwise	76.6		(+)
Farm size (ln)	Logged cultivable land area in hectares		-2.82 (1.43)	(+)
Number of parcels	Number of cultivable parcels managed by the HH		1.94 (1.51)	(+)
% Land ownership	Percent of cropland owned by the household		44.1 (46.3)	(+)
% Fertile farmland	Percent of cropland with moderate or high fertility		41.1 (47.1)	(−)
% Irrigation coverage	Percent of cropland with irrigation		16.6 (31.0)	(−)
% Low elevation AEZ	Percent of cropland in the low elevation AEZ		30.6 (42.2)	(±)
NGO or gov info	1 if received agricultural info from NGO or government; 0 otherwise	17.8		(+)
Peer info	1 if received agricultural info from family or neighbor farmer; 0 otherwise	31.5		(±)
Media info	1 if received agricultural info from print, radio or TV; 0 otherwise	7.7		(+)
Acopalca	1 if HH resides in Acopalca; 0 otherwise	12.2		(±)
Chamiseriía	1 if HH resides in Chamisería; 0 otherwise	4.6		(±)
Vilcacoto	1 if HH resides in Vilcacoto; 0 otherwise	10.5		(±)
Cochas Grande	1 if HH resides in Cochas Grande; 0 otherwise	13.6		(±)
Cochas Chico	1 if HH resides in Cochas Chico; 0 otherwise	35.0		(±)
Cullpa Alta	1 if HH resides in Cullpa Alta; 0 otherwise	24.1		

Note. Household is abbreviated "HH." Cullpa Alta is the base community for comparison in the regression analysis.

Gender of the head of household

Evidence from various sources indicates that gender plays an important role in shaping climate perceptions and adaptive responses. The presence of a male head of household is often positively associated with an agricultural household's tendency to perceive and respond to changes in climate (Deressa et al., 2009; Deressa et al., 2011; Ndambiri et al., 2012; Okonya et al., 2013). This trend is often attributed to the tendency for households led by a male member to have greater access to certain productive resources, especially information. If women are excluded from meetings or other social spaces where information about climate change and agricultural innovations is shared, then we would expect households led by female members to face additional barriers to climate perception and adaptation (Ogunlana, 2003). On the other hand, the presence of a female head of household may increase uptake of adaptive production practices in areas where women dominate the agricultural workforce and men tend to pursue off-farm economic activities (Nhemachena and Hassan, 2007).

Age and education of the head of household

Farmer attitudes and preferences are often associated with age and farming experience, and these characteristics tend to increase the likelihood that a household will adopt improved production technologies and sustainable resource management practices (Lee, 2005; Silvestri et al., 2012). However, these same factors may also be related to increased risk aversion, preferences for traditional production practices and household demographic patterns that could deter behavioral adjustments (Lee, 2005). Although several studies show positive effects of age and farming experience on climate perceptions (Deressa et al., 2011; Ndambiri et al., 2012; Okonya et al., 2013), age was shown to be negatively associated with adoption of soil and water management in Peru (de Graaff et al., 2008). One possible explanation for these mixed results is that the effect of age may be nonlinear (Debela et al., 2015).

Educational attainment tends to be associated with increased information and knowledge about changes in climate, improved production technologies and sustainable management practices. In the climate adaptation literature, studies have shown education to be positively correlated not only with the likelihood of perceiving climate change, but also with the accuracy of climate change perceptions (Ndambiri et al., 2012; Roco et al., 2015). Education also increases the likelihood of climate adaptation across a wide range of agricultural systems (Deressa, et al, 2009; Deressa et al., 2011; Silvestri et al., 2012; Abid et al., 2015).

Household size and percentage of household members under age five

Household size is often used to indicate a household's labor endowment (Silvestri, et al, 2012). If climate adaptive production practices are labor intensive, then we expect adaptation to be positively correlated with household size (de Graaff et al., 2008; Deressa et al., 2011; Abid et al., 2015). However, if household size is also correlated with the number of dependents in the household then it may confound labor availability with demographic status, especially given the considerable demands that infants and young children place on the time allocation of adult household members. Our model therefore includes the percentage of household members less than five years in age to control for a possible reduction in labor availability for households with infants and young children.

Wealth

Household wealth, or socioeconomic status, represents access to a range of physical, financial and social resources that may reduce a household's climate vulnerability and increase its adaptive capacity. Previous studies suggest that households with a higher socioeconomic status have better chances of perceiving and adapting to climate change (Deressa et al., 2011; Silvestri et al., 2012). Household income and asset ownership are common indicators of wealth. Both farm income and non-farm income are positively associated with the uptake of various climate adaptive practices by farmers in Ethiopia (Deressa et al., 2009). As per capita income rises, so does the propensity of farmers in Southern Africa to expand irrigation systems and water conservation measures in response to changes in climate (Nhemachena and Hassan, 2007).

The same study shows that the ownership of productive assets including tractors, heavy machinery and draft animals increases the likelihood of climate adaptation. In this analysis we include an asset-based index to control for household wealth. Using Principal Components Analysis (PCA) we derive a continuous, normalized measure of socioeconomic status from factor scores for 41 indicators of housing quality and asset ownership (Vyas and Kumaranayake, 2006). This method assumes that the first principal component represents socioeconomic status. The value of the wealth variable is a weighted sum of the observed values of each of the 41 asset indicators multiplied by their respective factor scores. Appendix 6 presents the PCA factor scores.

Comunero status

Communal life in much of the Andean highlands of Peru is inextricably linked to a democratic institution known as the *comunidad campesina* (peasant community). Just over three quarters of households in our sample are active *comunero* members, while the other 23% of households maintain agricultural practices without being inscribed as full members of the *comunidad campesina*. Gelles (2000) describes the basic functions of this respected and formally recognized social structure:

> [The Peasant Community] can legally act as a corporate body to defend communal interests from internal or external threats. Individuals are inscribed as *comuneros* into the Peasant Community. In return for attending communal assemblies and carrying out *cargos* and communal work service (*faena*), the *comunero* gains access to the common property resources of the community, such as irrigation water, grazing lands, medicinal herbs, and firewood. (p. 35).

Comunero status therefore indicates individual household access to communal resources, including key agricultural inputs. *Comunero* households may also benefit from access to local knowledge, social support and shared labor. We expect that *comunero* membership will increase a household's perception of climate impacts, and the likelihood of implementing adaptive responses, particularly when those responses depend upon communally managed land or water resources.

Farm size and number of parcels

Few empirical studies explore the relationship between farm size and climate perceptions (Gbetibouo, 2009). Moreover, empirical evidence suggests that larger agricultural landholdings may boost the propensity to adopt some adaptive practices, but reduce the uptake of others. Households with smaller landholdings were more likely to adopt climate adaptive measures in Uganda (Okonya et al., 2013) and Ethiopia (Deressa et al., 2011), yet farming households with larger landholdings were more likely to switch crops and varieties in response to climate change in Pakistan (Abid et al., 2015). Research from Peru suggests that investment in soil and water conservation also increases with farm size (de Graaff et al., 2008). The relationship between farm fragmentation or farm complexity and these outcomes is also ambiguous, although Nhemachena and Hassan (2007) show that diversified farming systems can be more conducive to climate adaptation.

Andean farming systems are dominated by smallholders, yet individual farms are often highly fragmented, with production activities taking place on multiple parcels located at different elevations and in distinct agroecological zones (Perez et al., 2010). Together, farm size and the number of parcels indicate the scale and complexity of a household farming system. In this context, we expect households with larger landholdings and a greater number of parcels to be more invested and more actively engaged in agriculture, and therefore more likely to experience and report negative impacts of climate change. Regarding adaptation, we expect farm size to be associated with the uptake of adaptive practices that are land intensive, such as tree planting and irrigated agriculture. We further expect the number of parcels to be positively associated with farm production diversity, and therefore also with the likelihood of producing native potato varieties.

Land ownership

Andean agriculture is characterized by a variety of tenancy arrangements, which include land ownership, land rental, sharecropping, and individual or shared use of communal lands. Some households manage multiple parcels under different tenancy arrangements, so we define this variable as the percentage of total farmland under household ownership. Within this context, land ownership represents secure household access to a significant productive asset that reduces the risk of long-term investments. Empirical evidence suggests that land ownership enhances climate perceptions (Roco et al., 2015), and that "private property increases uptake of adaptation measures" (Nhemachena and Hassan, 2007). Specifically, we expect land ownership to increase the likelihood of selecting adaptive practices that are characterized by significant initial investment and a relatively long payback period.

Soil fertility

Empirical evidence regarding the effects of soil fertility on climate perceptions and adaptations differs depending on the context. Research from Kenya shows that households with more fertile farms are more likely to perceive climate change (Ndambiri et al., 2012), while a study from South Africa concludes that high soil fertility increases the likelihood of perceiving changes in rainfall, but decreases the chance of perceiving changes in temperature (Gbetibouo, 2009). However, work from Ghana showed that households with more fertile farms were more likely to adapt to changes in temperature, but less likely to adapt to changes in rainfall (Fosu Mensah et al., 2012). If high soil fertility moderates climate impacts, perhaps through improved soil capacity to absorb and retain moisture, then we expect soil fertility to be negatively associated with climate perceptions and the likelihood of adaptation (Perez et al., 2010).

Irrigation coverage

Irrigation is considered to be a valuable climate adaptive strategy, particularly in the face of uncertain precipitation and increasing drought frequency. However, little is known about the effects of irrigation on the propensity to adopt other climate adaptations, in part because irrigation is more often modeled as a dependent variable. This question is of particular interest, given the strong evidence that access to irrigation reduces the chance that a farmer will perceive climate change (Gbetibouo, 2009; Ndambiri et al., 2012). We therefore include irrigation as a dependent variable, defined as the percent of a household's total cultivable land that is irrigated. This variable used to model climate perceptions and three of our four adaptations: growing native potato, planting trees and practicing soil or water conservation. We cannot include irrigation coverage as a predictor of irrigation use. To the extent that irrigation buffers impacts of climate change, we expect it to be negatively associated with climate perceptions and adaptations.

Agroecological zone

Numerous studies stress the importance of local agroecology and associated variables such as elevation, rainfall and temperature for climate perception and adaptation (Hassan and Nemachena, 2008; Seo and Mendlesohn, 2008; Deressa et al., 2009; Hisali et al., 2011; Okonya et al., 2013). To control for agroecological zone (AEZ), we include an explanatory variable representing the percentage of a household's farmland located in the low elevation *quechua* zone. In general, this zone is characterized by flatter land and a warmer, milder climate compared to higher elevations. Thus, we expect the proportion of land in the low elevation AEZ to be positively associated with the irrigation choice outcome, but negatively associated with the propensity to plant native potato varieties, which are more resistant to cold and drought. Furthermore, empirical evidence suggests that farmers in Peru invest more in soil and water conservation in the *quechua* zone because the land tends to be more productive (de Graaff et al., 2008).

Agricultural information sources

Information delivery has long been considered a critical component of shaping problem awareness and attitudes among farmers, and as an important step toward improved farm management and technology adoption (Lee, 2005). Results from empirical studies overwhelmingly emphasize the positive effects of climate information, weather forecasting and extension services on climate perceptions (Ndambiri et al., 2012; Debela et al., 2015), and on the likelihood of adaptation (Hassan & Nemachena, 2008; Fosu Mensah et al., 2012; Abid et al., 2015). Studies emphasizing specific information sources show that farmer-to-farmer extension increases the likelihood of perceiving climate change among farmers in Ethiopia (Deressa et al., 2011), while access to weather information from mass media and from the Internet improves the accuracy of climate perceptions among Chilean farmers (Roco et al., 2015). Deressa et al. (2009) examined the effects of three types of information – traditional crop and livestock extension, farmer-to-farmer extension and climate change information – on five different adaptive production practices. All three information sources were positively associated with farmer uptake of multiple adaptive outcomes, and farmer-to-farmer extension was positively associated with all five choice outcomes.

Our model includes indicator variables representing three distinct sources of agricultural information: NGO or government sources; family or neighbor farmers; and radio, television or print media. We expect access to information about agriculture from NGO or government extension providers, and from media sources, will be positively associated with climate perception and adaptation outcomes. The expected effect of peer information is less clear. Although previous studies suggest that farmer-to-farmer extension increases the likelihood of perceiving and adapting to climate change (Deressa et al., 2009; Deressa et al., 2011), our peer information variable does not reflect any structured exchange of information among farmers. Indeed, farmer-to-farmer extension programs in other parts of the world are typically structured and facilitated by NGOs or government entities, and they often rely on experienced and highly respected mentor farmers to communicate messages or demonstrate technologies from an outside source. Our peer information variable broadly indicates access to agricultural information from family or neighbor farmers, but it does not provide much information about the type or quality of the information being shared.

Village of residence

We introduce dummy variables for village of residence into our models to control for village effects. The six villages in our study are distributed across an elevation gradient, with elevation being positively correlated with the distance to input and output markets in Huancayo, and negatively correlated with the degree of urbanization. Although our data do not allow us to disentangle the individual effects of elevation, temperature, precipitation or distance to markets on climate perceptions and adaptations, the coefficients on the village dummy variables can provide insight into these interrelated dynamics.

2.4.5 Empirical challenges

Econometric analysis with cross-sectional data is often complicated by estimation problems, including heteroskedasticity, multicollinearity and high sensitivity to the effects of spurious outliers (Nhemachena & Hassan, 2007). Heteroskedasticity in regression analysis causes biased standard error estimates, which invalidates statistical inference. To address the possibilities of heteroskedasticity in our analysis, we specify robust standard errors for linear (climate perception) and logistic (climate adaptation) regression models. Throughout the analysis, we use robust standard errors to infer statistical significance levels for coefficient estimates (StataCorp, 2015).

We address the impact of possible outliers by winsorizing all of the continuous explanatory variables. Values for each variable are truncated at the 10^{th} and 90^{th} percentiles: any value below the 10^{th} percentile is set to the value of the 10^{th} percentile, and any value above the 90^{th} percentile is set to the 90^{th} percentile. This process creates an estimator that is more robust to effects of outliers, and, unlike trimming, it retains all of the original observations. A comparison in Appendix 2 shows only minor differences in the results for models using original and winsorized data.

Although multicollinearity does not reduce the efficiency or reliability of an overall model, it may result in inaccurate coefficient estimates for individual parameters. A simple two-way correlation analysis reveals a high degree of collinearity among the eleven continuous explanatory variables in our model, as 35 of the 66 possible pairs are significantly correlated at a 10% confidence level (Table 2.3). To assess the level of multicollinearity in our regression models we calculate the Variance Inflation Factor for each explanatory variable by regressing it on all of the other predictors and taking the inverse of the tolerance ($VIF = 1/(1 - R^2)$). If we exclude the quadratic age term, which is highly collinear with the actual age of the household head, then the VIF values range from 1.13 to 2.00 with a mean of 1.48 (Table 2.4). These values are well below the conventional cutoff VIF of 10, implying that multicollinearity is not a serious problem in this particular specification (O'Brien, 2007). The variables age and age-squared both have high VIF values when the quadratic term is included, yet this specification does not appear to inflate VIF values for the other predictors in the model. We retain the quadratic age term in order to capture possible nonlinearities in the relationship between age and the various outcome variables.

Factor analysis offers an alternative method to address the problem of multicollinearity in regression analysis with cross-sectional data. We conduct a factor analysis of the 13 original explanatory variables representing household and farm characteristics (excluding the quadratic age term) and extract three underlying factors that roughly represent (1) demographic status, (2) farm size and productive assets, and (3) farm ownership and infrastructure. Appendix 4 presents regression results using these three factors in place of the 13 original predictors to explain climate perceptions and uptake of adaptive production practices.

Table 2.3

Pairwise Correlation Coefficients for Continuous Explanatory Variables (N=286)

	Age	Age squared	Education	Household Size	% Members < 5 yrs	Wealth
Age	1.00					
Age squared	0.99 ***	1.00				
Education	-0.38 ***	-0.38 ***	1.00			
Household size	-0.23 ***	-0.27 ***	0.14	1.00		
% Members < 5 yrs	-0.59 ***	-0.56 ***	0.36 ***	0.16 ***	1.00	
Wealth	-0.16 ***	-0.17 ***	0.39 ***	0.08	0.27 ***	1.00
Farm size (ln)	0.15 ***	0.14 **	0.12 *	0.03	-0.17 ***	0.23 ***
Number of parcels	0.04	0.03	0.04	0.06	-0.06	0.20 ***
% Land ownership	0.23 ***	0.23 ***	-0.00	-0.01	-0.13 **	0.05
% Fertile farmland	-0.01	-0.00	-0.04	-0.10 *	-0.02	-0.08
% Irrigation	0.03	0.04	-0.04	-0.07	0.02	-0.06
% Low elevation	0.17 ***	0.18 ***	-0.11 *	-0.08	-0.06	-0.06

	Farm size (ln)	Number of parcels	% Land ownership	% Fertile farmland	% Irrigation coverage	% Low elevation
Farm size (ln)	1.00					
Number of parcels	0.54 ***	1.00				
% Land ownership	0.25 ***	0.18 ***	1.00			
% Fertile farmland	-0.15 **	0.00	-0.05	1.00		
% Irrigation cov.	0.06	-0.16 ***	0.35 ***	-0.07	1.00	
% Low elevation	-0.07	-0.09	0.17 ***	0.15 **	0.25 ***	1.00

Note. *** p<0.01, ** p<0.05, * p<0.1.

Table 2.4

Variance Inflation Factor (VIF) for Explanatory Variables (N=286)

VARIABLES	Excluding quadratic age term		Including quadratic age term	
	VIF	R^2	VIF	R^2
Female	1.18	0.1555	1.20	0.1675
Age	1.93	0.4809	115.31	0.9913
Age squared			111.45	0.9910
Education	1.51	0.3363	1.51	0.3363
Household size	1.14	0.1207	1.38	0.2762
% Members < 5 yrs	1.91	0.4763	2.15	0.5354
Wealth	1.64	0.3896	1.69	0.4077
Comunero status	1.29	0.2242	1.37	0.2707
Farm size (ln)	1.77	0.4342	1.77	0.4344
Number of parcels	1.81	0.4471	1.81	0.4472
% Land ownership	1.44	0.3067	1.45	0.3120
% Fertile farmland	1.19	0.1587	1.19	0.1588
% Irrigation coverage	1.34	0.2526	1.34	0.2534
% Low elevation AEZ	1.22	0.1828	1.23	0.1852
NGO or government info	1.26	0.2045	1.26	0.2061
Peer info	1.27	0.2139	1.27	0.2154
Media info	1.13	0.1146	1.14	0.1220
Acopalca	1.87	0.4665	1.88	0.4667
Chamisería	1.28	0.2187	1.28	0.2200
Vilcacoto	1.42	0.2981	1.42	0.2982
Cochas Grande	1.50	0.3335	1.52	0.3440
Cochas Chico	2.00	0.5012	2.01	0.5032
Mean VIF	1.48		11.67	

2.5 RESULTS AND DISCUSSION

2.5.1 Climate perceptions

Farmers in our sample overwhelmingly report that climate is changing. Fully 100% of farmers who have lived in their current village for at least ten years (N=240) reported three or more changes in climate over the past decade (Table 2.5). The most commonly reported climate changes relate to precipitation, as over 90% of farmers reported changes in the duration of the rainy season, the intensity of the rains, the number of dry days during the rainy season and the intensity of wind. A majority of farmers also perceived changes in the timing of the rainy season, the water level in local streams and rivers, the frequency of droughts, the duration of the frost season and the frequency of unseasonable frosts. Fewer than half of farmers observed a change in the frequency of flooding or other changes related to climate. Farmers widely reported negative impacts on food production associated with changing climate and weather patterns, although not every perceived change had a damaging effect on crops. The Climate Impact Score (CIS) ranged from 0 to 33, with a mean of 13.95 and a standard deviation of 7.79 (Figure 2.2).

Table 2.5

Farmer Perceptions of Climate Changes and Resulting Impacts (N=240)

Reported Changes in Climate	**% of Respondents**		**Climate Impact Scale**
	Observed the change	Change impacted crops	Mean (SD)
Intensity of the rains	94	79	1.6 (1.1)
Duration of the rainy season	94	77	1.5 (1.1)
Number of dry days during rainy season	92	76	1.6 (1.1)
Intensity of the wind	91	70	1.5 (1.2)
Water level in the rivers	90	58	1.3 (1.2)
Start of the rainy season	86	72	1.4 (1.0)
Duration of the frost season	80	64	1.3 (1.2)
Frequency of droughts	80	64	1.2 (1.1)
Number of frost events outside frost season	73	55	1.1 (1.1)
Frequency of floods	47	27	0.5 (0.9)
New crop pests or diseases	35	33	0.8 (1.1)
Other climate change	14	11	0.2 (0.7)

Summary of Climate Observations	**Mean (SD)**	**Min**	**Max**
Number of climate changes observed	8.8 (1.7)	3	12
Number of climate impacts reported	6.9 (2.9)	0	12
Climate Impact Score (CIS)	13.95 (7.79)	0	33

Note. Climate impacts to agriculture are rated on a 0 to 3 point scale (0 = no impact; 1 = low impact; 2 = moderate impact; 3 = high impact).

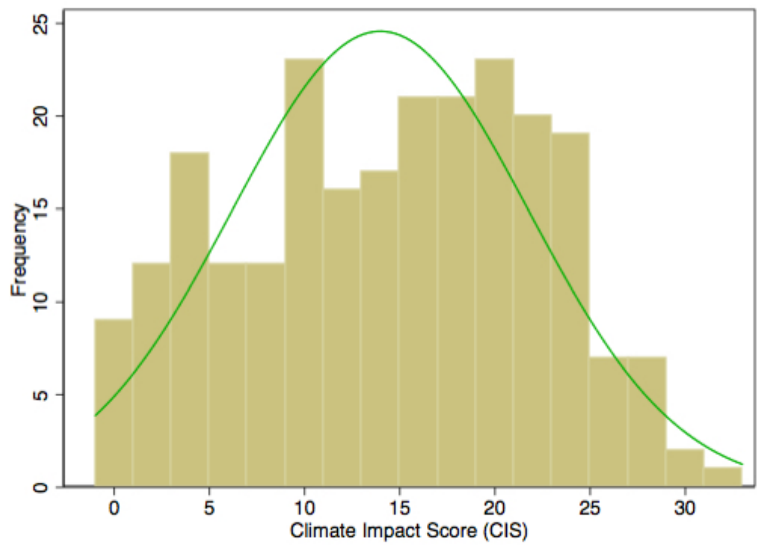

Figure 2.2. Frequency histogram of the Climate Impact Score with overlaid normal density plot. Observations are based on the sub-sample of households with at least 10 years of residence in their current village (N=240).

Table 2.6 presents OLS coefficient estimates from a linear regression model with Climate Impact Score (CIS) as the continuous outcome variable. The model is highly significant ($F = 9.43,\ p < 0.0001$), and explains 39.2% of the variation in CIS. The results identify a nonlinear relationship between age and climate perceptions. CIS increases with age until about age 50, then decreases with age at an increasing rate. As expected, education is significantly positively correlated with perceived climate impacts: each additional year of education translates into 0.38-point increase in CIS, on average. This finding suggests that households with higher educational attainment may have enhanced access to, or ability to interpret, climate information.

Household perceptions of climate impacts decrease significantly as the percentage of fertile land and the percentage of irrigation coverage increase, respectively. This result suggests that irrigation buffers the impacts of climate change, particularly those changes related to uncertain precipitation or drought (Gbetibouo, 2009; Ndambiri et al., 2012). It further suggests that soil quality may play a similar role in moderating climate impacts. In theory, soil fertility tends to be associated with higher organic matter content, which supports water infiltration and retention (Berazneva et al., 2016). This relationship is one possible mechanism that could link higher soil fertility to reduced perceptions of climate impact. Access to objective soil quality measures would help to verify this interpretation, since we rely on a subjective measure of soil quality rather than objective soil tests.

Table 2.6

Perceived Climate Impact (N=240)

VARIABLES	(1) Climate Impact Score
Female	-1.022
	(0.892)
Age	1.169***
	(0.307)
Age squared	-0.0116***
	(0.00307)
Education	0.383**
	(0.159)
Household size	-0.425
	(0.290)
% Members < 5 yrs	0.0331
	(0.0489)
Wealth	0.0610
	(0.0942)
Comunero status	0.293
	(1.248)
Farm size (ln)	0.00120
	(0.479)
Number of parcels	0.437
	(0.689)
% Land ownership	0.00319
	(0.0106)
% Fertile farmland	-0.0225**
	(0.0102)
% Irrigation coverage	-0.0268*
	(0.0154)
% Low elevation AEZ	-0.00869
	(0.0107)
NGO or government information	1.357
	(1.181)
Peer information	-8.656***
	(1.031)
Media information	2.894*
	(1.597)
Acopalca	-1.206
	(1.675)
Chamisería	-0.405
	(3.079)
Vilcacoto	-1.205
	(1.460)
Cochas Grande	-1.861
	(1.514)
Cochas Chico	-3.122**
	(1.347)
Constant	-10.70
	(7.913)
Observations	240
R-squared	0.3919

Note. Coefficient estimates from OLS regression. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

The relationships between information sources and perceptions of climate impacts are not all as we had expected. We find no evidence of an association between agricultural information from NGO or government sources and perceived climate impacts. Agricultural information from media sources is positively correlated with CIS, as expected, yet the correlation between CIS and peer information is negative, significant and large. Access to media information results in a 2.9-point increase in CIS, on average, while household access to agricultural information from peers reduces CIS by an average of 8.7 points. Without additional qualitative information on the content of information shared between peers, it is difficult to interpret this result. However, we offer several conjectures. First, if agricultural information shared among peers is wrong, then peer-to-peer information networks may be spreading misinformation about climate impacts. Second, it is likely that households share similar characteristics with their peers, and may therefore receive information from family and neighbor farmers who share similar characteristics or attitudes. If this is true, then peer information may serve to reinforce prior household beliefs. Third, the peer information variable may represent social capital or community cohesion rather than access to a specific type of information. However, indicators of social capital are also expected to be positively associated with climate perceptions (Deressa et al., 2011).

2.5.2 Climate adaptations

Despite widespread perceptions of climate change and its associated impacts on agriculture, only 42 out of 286 households (14.7%) reported consciously adjusting one or more production practices in response, while 85.3% reported no conscious adaptations. Farmers that have explicitly adapted to changes in climate identified a variety of adaptation strategies in an open-ended survey question, including changes to the timing of planting or harvesting, changes in the type of crops or varieties planted, and changes to a wide range of other farm management practices including soil management, water management, irrigation, burning and tree planting. The frequency of conscious adaptation is in our sample is extremely low compared to findings from eleven other studies, summarized in Table 2.7, that report climate adaptation rates ranging from 21% to 85% among agricultural households in developing countries. It is possible that adaption rates are relatively low due to some particularity of Andean farming systems, since most of these studies listed in Table 2.7 use survey data from African countries, and none of them takes place within the Andean region. Alternatively, the findings from prior studies may reflect a degree of social desirability bias. If survey respondents perceive that reporting climate perceptions or adaptations will please researchers, they may overstate their perceptions or adaptations. The likelihood of social desirability bias depends on survey design, the wording of survey questions, and the way that researchers introduce the study to respondents. This conjecture is purely speculative, as detailed information on survey structure and delivery is not readily available for most studies. However, we carefully considered the problem of social desirability bias and worked to minimize it in the design and delivery of our household survey. Thus, the difference we observe may reflect overstated rates of climate adaptation in previous studies.

Table 2.7

Summary of Climate Change Perception and Adaptation Rates in Developing Countries

			Perceptions		Adaptations	
Authors	Year	Location	Sample Size	Perception Rate	Sample Size	Adaptation Rate
Abid et al.	2015	Pakistan	450	91%	450	58%
Bryan et al.	2013	Kenya	710	94%	710	81%
Debela et al.	2015	Ethiopia	480	96%		
Deressa et al.	2011	Ethiopia	1,000	83%	1,000	48%
Fosu Mensah et al.	2012	Ghana	180	91%	180	44%
Gbetibouo	2009	South Africa	794	97%	794	38%
Ndambiri et al.	2012	Kenya	246	94%		
Nhemachena and Hassan	2007	South Africa, Zambia and Zimbabwe	1,719	86%	1,719	77%
Okonya et al.	2013	Uganda	192	99%	192	85%
Roco et al.	2015	Chile	274	93%		
Silvestri et al.	2012	Kenya	640	97%	640	21%
Sum			6,685		5,685	

Weighted average	91%	58%

Notwithstanding low rates of conscious adaptation, a majority of households in our sample (84.6%) do report using one or more climate adaptive farming practices (Figure 2.3). Climate adaptive production practices, or implicit adaptations, refer to agricultural measures that are expected to reduce climate vulnerability and enhance adaptive capacity at the farm level, among other outcomes. The researcher-identified list of implicit adaptations for our study area includes native potato production, tree planting, irrigation and numerous soil and water conservation practices, among others. Farmers may choose to adopt such measures for any number of reasons, yet few farmers considered them to be a direct response to climate change. For example, 120 households (42.0%) reported planting trees within the past three years, but only five households (1.8%) identified tree planting as a conscious measure to address the consequences of climate change (Figure 2.4). The dramatic difference in uptake of explicit versus implicit adaptation measures underscores the reality that climate change is just one of many livelihood risks that rural households face, and in many cases it may not be the most pressing (McDowell & Hess, 2012; Gandure et al., 2013).

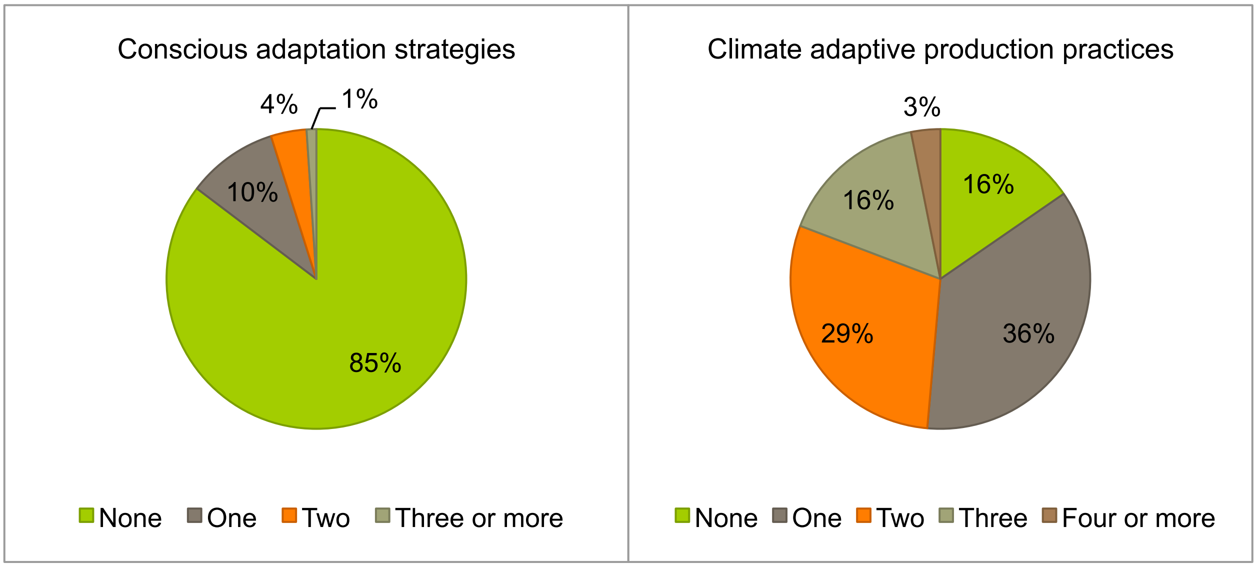

Figure 2.3. Number of agricultural adaptations taken up per household (N=286). *Conscious adaptation strategies* refer to practices that farmers have implemented in direct response to changes in climate. These explicit adaptation strategies, identified by the farmers themselves in an open-ended question, include changes to: the timing of sowing, the crops or varieties planted, burning practices, soil management practices, water management practices, irrigation practices and tree planting. *Climate adaptive production practices* refer to specific agricultural practices identified by researchers that are expected to reduce the magnitude and the risk of projected climate impacts. They include: growing native potato, planting trees, irrigating fields and implementing any soil or water conservation practice. Farmers may choose to adopt such practices for any number of reasons, yet few farmers identify them as direct responses to changes in climate.

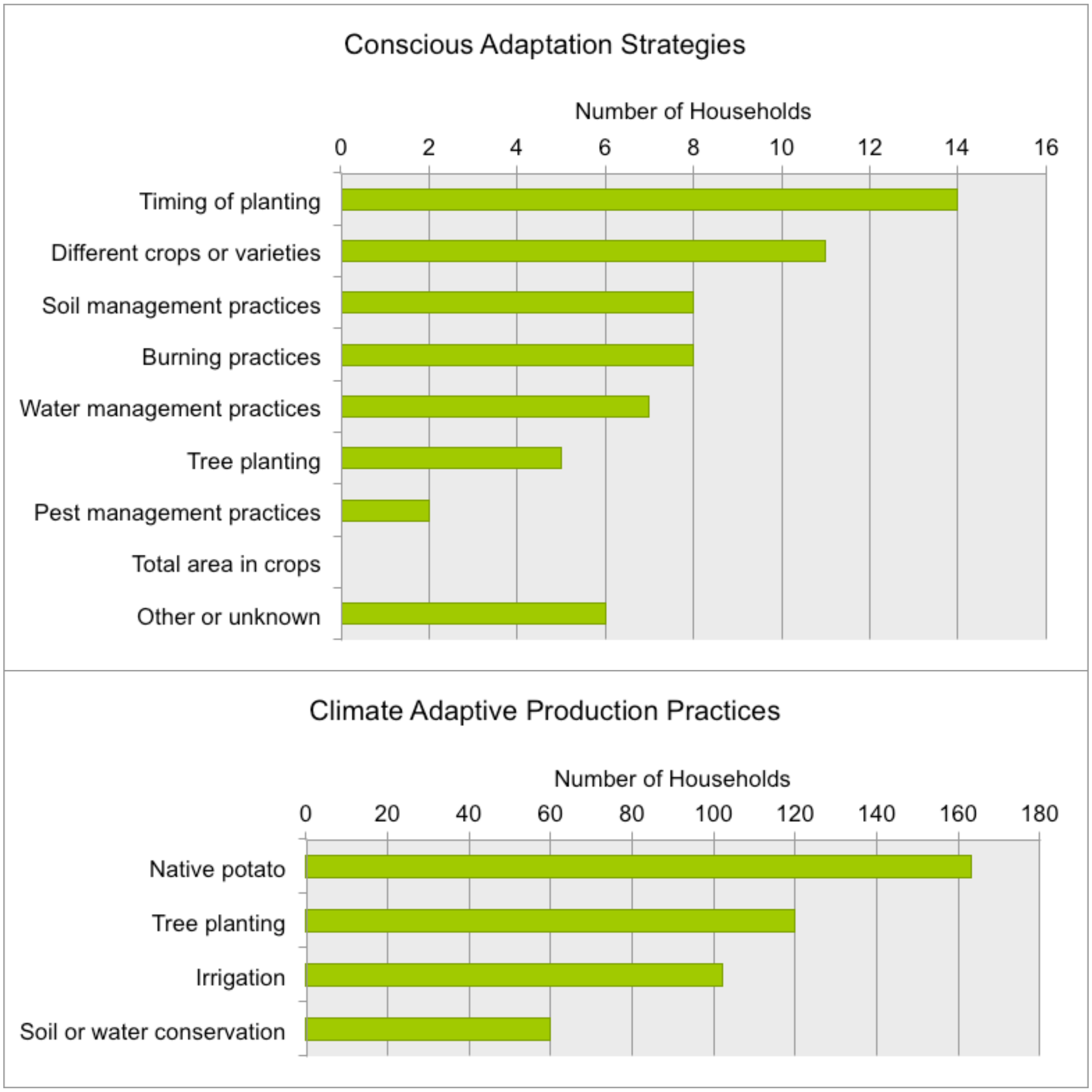

Figure 2.4. Prevalence of conscious responses compared to adaptive production practices (N=286).

Table 2.8 presents the marginal effects of each explanatory variable on the likelihood of adaptation based on four independently estimated logit models. Dependent variables represent the binary adoption choice for four important climate adaptive production practices identified through our household survey: (1) growing native potato; (2) planting trees; (3) irrigation; and (4) soil or water conservation. All four logistic regression models are significant, with $\chi^2 > 46$ and associated p-values ≤ 0.002, while pseudo-R^2 values range from 0.16 to 0.32. Each adaptation choice outcome was significantly associated with at least one household characteristic and at least one farm attribute, except for uptake of soil or water conservation, which was associated with farm attributes but not household characteristics. There was considerable variation across the four models in terms of which explanatory variables best predicted variation in outcomes. For example, household characteristics seem to be relatively more important in explaining the likelihood of planting trees, while farm attributes appear to be more important for explaining variation in the propensity to use irrigation and grow native potato. Village effects are significant in all three models, but they appear to be most important for explaining variation in the native potato choice outcome.

Only one explanatory variable was significantly correlated with all four outcomes: the percentage of fertile farmland was negatively associated with each of the four climate adaptive production practices. Thus, farmers with a greater percentage of land characterized by poor soil quality are more likely to grow native potato, plant trees, use irrigation and adopt conservation measures. This finding is consistent with agronomic evidence that native potato varieties, along with native tuber crops *oca*, *olluco* and *mashua*, are better physiologically suited for marginal lands relative to other crops (Ramírez et al., 2001; Perez et al., 2010). Furthermore, crops such as maize, broad bean and modern potato varieties may offer relatively higher economic yields on fertile parcels. Similarly, some tree species may thrive on marginal lands where cultivation of annual crops is not feasible, yet the considerable initial investment associated with tree planting is unlikely to be an attractive alternative to food crop production on higher quality parcels.

Table 2.8

Likelihood of Climate Adaptive Practices (N=286)

VARIABLES	(1) Native Potato	(2) Trees	(3) Irrigation	(4) Soil or water conservation
Female	-0.0439	0.106*	0.0173	0.0292
	(0.0548)	(0.0627)	(0.0548)	(0.0524)
Age	-0.00987	0.000445	0.0173	0.0213
	(0.0196)	(0.0208)	(0.0182)	(0.0190)
Age squared	5.21e-05	-5.65e-05	-0.000192	-0.000229
	(0.000197)	(0.000208)	(0.000181)	(0.000193)
Education	-0.00190	0.0240***	-0.00456	0.0116
	(0.00864)	(0.00931)	(0.00871)	(0.00777)
Household size	-0.0189	0.0294	-0.0233	0.00456
	(0.0189)	(0.0187)	(0.0163)	(0.0154)
% Members < 5 yrs	-0.00298	-0.00741**	0.00252	-0.00270
	(0.00292)	(0.00309)	(0.00276)	(0.00260)
Wealth	0.000678	-0.00296	-0.00570	0.000719
	(0.00495)	(0.00594)	(0.00507)	(0.00479)
Comunero status	0.160**	0.00903	0.108*	-0.0911
	(0.0670)	(0.0722)	(0.0639)	(0.0686)
Farm size (ln)	-0.00234	0.0295	0.0579**	-0.000837
	(0.0283)	(0.0301)	(0.0256)	(0.0278)
Number of parcels	0.0428	0.0441	0.108***	0.00672
	(0.0385)	(0.0423)	(0.0364)	(0.0332)
% Land ownership	-0.000936	0.000255	0.00300***	-0.000150
	(0.000667)	(0.000691)	(0.000504)	(0.000590)
% Fertile farmland	-0.00177***	-0.00157***	-0.00114*	-0.00115**
	(0.000582)	(0.000592)	(0.000584)	(0.000543)
% Irrigation coverage	-0.00240**	0.000811		0.00140*
	(0.00104)	(0.000967)		(0.000811)
% Low elevation AEZ	-0.00126**	0.00163**	0.00193***	0.000282
	(0.000589)	(0.000664)	(0.000596)	(0.000600)
NGO or government information	0.109	0.262***	0.0692	0.189**
	(0.0819)	(0.0778)	(0.0659)	(0.0806)
Peer information	-0.218***	0.0668	-0.0255	-0.0970**
	(0.0617)	(0.0660)	(0.0594)	(0.0479)
Media information	0.0386	0.187	-0.0173	0.352***
	(0.107)	(0.118)	(0.0819)	(0.0992)
Acopalca	0.498***	0.355***	-0.0226	-0.104
	(0.0303)	(0.0900)	(0.0960)	(0.0762)
Chamisería	-0.123	0.0265	-0.239**	-0.0354
	(0.114)	(0.161)	(0.0937)	(0.117)
Vilcacoto	0.244***	0.121	-0.0556	0.204**
	(0.0671)	(0.106)	(0.0807)	(0.104)
Cochas Grande	0.221***	0.0471	0.0113	0.0203
	(0.0657)	(0.100)	(0.0822)	(0.0835)
Cochas Chico	0.188***	0.128*	-0.0420	0.0884
	(0.0579)	(0.0767)	(0.0712)	(0.0700)
Observations	286	286	286	286
Wald chi-squared	60.63	57.06	71.63	46.06
P-value	0.0000	0.0001	0.0000	0.0019
Pseudo R-squared	0.3164	0.1610	0.2513	0.1593

Note. Coefficient estimates from logistic regression. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

The negative relationship between soil fertility and the propensity to use irrigation is surprising, as we would expect a higher return to the irrigation investment on better-quality land. Perhaps this finding reflects a more complex, two-way relationship between irrigation and soil fertility, which may be due to the time scale over which farmers practice irrigation. Even if farmers initially install irrigation systems on more fertile parcels, the use of irrigation may negatively affect soil fertility, particularly if irrigated parcels are farmed more intensively. This explanation seems reasonable when we consider that farmers in the Peruvian highlands complete a single crop cycle per year on rainfed parcels, yet some growers achieve multiple harvests per year on irrigated plots. Below we describe in more detail the regression results for each climate adaptive outcome.

Native potato

A household's likelihood of cultivating native potato was positively associated with *comunero* status, while being negatively associated with irrigation coverage and the percent of farmland in the low elevation AEZ. *Comunero* status indicates access to communal land and other forms of natural and human capital, which include shared labor during organized community workdays (Winder, 1978). *Comunero* households may also have preferential access to information and local knowledge associated with traditional crops, varieties and production practices. Our results imply that native potato production relies in part on access to the natural and social resources belonging to, and allocated by, the *comunidad campesina*.

Agricultural plots in the low elevation *quechua* zone are suited to a much broader range of crops compared to the middle elevation *suni* zone, with its harsher climate. It is therefore unsurprising that farmers with more land in the low elevation AEZ are less likely to plant native potato. Moreover, controlling for the percentage of farmland in the *quechua* zone, our model estimates a significant negative association between irrigation coverage and the propensity to plant native potato, *ceteris paribus*. By moderating the effects of uncertain precipitation, irrigation coverage likely reduces the incentive to plant hardier, drought-tolerant crops and varieties (Perez et al., 2010). Irrigation coverage may therefore deter farmers from growing native potato, encouraging them to instead plant crops that are less hardy, and therefore riskier, but perhaps more profitable.

Agricultural information from peers was significantly negatively correlated with the likelihood of growing native potato, while coefficient estimates on the other two information sources were positive but insignificant. This result is surprising, as we would expect information about traditional crop varieties and production practices to be shared through peer networks. However, work to popularize modern potato varieties, combined with a perception of higher consumer demand for modern potato, may result in a different message being shared among farming households (Pradel et al., 2013). Additional research is needed to better identify farmer preferences for specific potato traits, and how those preferences affect the way agricultural information is shared among farming households.

Alternatively, this unexpected result may signal a problem of bias or endogeneity with the peer information variable. It is possible that, despite the many controls included in our model, household receipt of information from peers varies systematically with some unobserved characteristic that is also correlated with the outcome variable. Or there may be a problem of reverse causality if households growing modern potato varieties are more socially connected and therefore more likely to seek out information or advice from peers. To further explore the problem of selection bias for the various information "treatments" we independently estimate binary logit models that predict receipt of information from the three different sources, and selection into a group that receives no information (Appendix 3). Residence in Acopalca, which dramatically increases the likelihood of native potato adoption (Table 2.8), also reduces the likelihood of receiving information from peers by 20%, on average (Table A2.7). Since Acopalca is the village that has been most affected by migration and population decline over the past decade, this result hints that peer information networks may be related to social cohesion at the village level.

Tree planting

The likelihood of planting trees is positively associated with agricultural information from formal extension sources. This outcome is not surprising given the extensive government and NGO investment in education and outreach related to tree planting in the Shullcas River watershed in recent years (CARE, 2012). Reforestation projects within this zone have been especially targeted toward residents of Acopalca, which is nearest to the Huaytapallana glacier, with the goal of improving water infiltration and aquifer recharge. Our model reflects the impact of this geographic focus in the coefficient estimate for the Acopalca indicator. On average, a household residing in Acopalca is 31% more likely to plant trees relative to a household in the base community of Cullpa Alta, *ceteris paribus*.

Additionally, the likelihood of planting trees was significantly correlated with several household characteristics. Echoing the findings of Abid et al. (2015), a positive association with education suggests that tree planting is information and knowledge intensive. Contrary to some studies that claim women farmers are slow to adopt innovative production practices, households in our sample in which the primary decision maker is female are *more* likely to plant trees, holding all else equal. In fact, 49.4% of households with a female head of household reported planting trees in the past three years, compared to just 38.8% of households with a male decision maker. These results suggest that local NGO efforts to promote tree planting may have overcome a common barrier to supporting women's technology adoption by actively including women in meetings where information is shared and benefits of the technology are discussed (Ogunlana, 2003). Indeed, 22.4% of the 85 households led by female decision makers reported receiving information from NGO or government sources, compared to only 15.9% of the 201 households with male heads of household. Given that local NGO efforts to reduce climate vulnerability also emphasize gender equity and inclusion, this result is very promising. Moreover, the negative association between the proportion of household members less than five years old and the propensity to plant trees suggests that tree planting is labor intensive. Therefore, this production practice may conflict with the demands of caring for young children. Childcare responsibilities may also may impede participation in community meetings or educational events. This finding is particularly noteworthy given not only the importance of gender as a driver of adoption, but also the emphasis on gender equity and inclusion.

As described above, households with more fertile farmland are less likely to plant trees, suggesting that farmers prefer to adopt this practice on marginal land. However, households with a higher percentage of land in the low elevation *quechua* zone are more apt to adopt this practice. Although NGO and government outreach efforts have targeted higher elevation communities, this result indicates that tree planting is not incompatible with farming practices at lower elevations.

Irrigation use

The only household characteristic to be significantly correlated with the likelihood of irrigation use was *comunero* status. Holding all else equal, active *comunero* membership increases the likelihood of using irrigation by 12%, on average. Irrigation likely relies on communal resources, the most apparent of which is water. *Comunero* members may have preferential rights to use water for irrigation purposes, and preferential access to communally managed infrastructure, such as water catchment ponds or irrigation canals, that support individual irrigation systems. As a result, regardless of individual preferences for irrigation, households that are not *comunero* members may face hard constraints to developing their own irrigation systems. Furthermore, *comunero* households likely have differential access to some types of agricultural information, which may not be captured in our information indicator variables. Although we find no significant association between information sources and a household's propensity to use irrigation, we suspect that information exchanged among *comunero* farmers at formal and informal gatherings may support the use and maintenance of household irrigation systems.

The irrigation outcome was also positively associated with multiple farm attributes.

Households with larger and more complex farms (as indicated by the number of parcels) are more likely to use irrigation. Irrigation represents a durable asset that requires significant initial investment, with associated financial risk. It is therefore unsurprising that households owning a greater portion of their total productive land area will be more likely to invest in irrigation. Agroecological zone is also important for predicting irrigation use. Topography in the lower elevation *quechua* zone tends to be flatter and more conducive to irrigation infrastructure. In contrast, the topography at higher elevations, particularly around the village of Chamisería tends to be steeper and less productive, which discourages investment in irrigation. Furthermore, village leaders in Chamisería report relocating communal farming activities to a new site every few years. Thus, it is unsurprising that residence in the Chamisería reduces the likelihood of irrigation use.

Soil or water conservation

Of all the adaptive practices we examine, soil and water conservation appears to be the most sensitive to agricultural information from various sources. On average, information from formal (NGO or government) and media sources increases the propensity to adopt one or more conservation practices by 18.9% and 35.2%, respectively, while information from peers decreases the chances of adoption by 9.7%. These findings reinforce the importance of agricultural information from traditional extension providers, and from media sources, for the adoption of sustainable farm management practice that conserve soil and water resources. The negative relationship between peer information and the adaptation outcome is unexpected and difficult to explain without additional knowledge about the content of the agricultural information that is shared through peer networks. Households with a greater percentage of irrigated land are more likely to practice soil or water conservation, indicating that these two practices may be complementary adaptation strategies.

2.6 CONCLUSIONS

This study documents widespread perceptions of climate change, but low rates of conscious adaptation among farming households within the Shullcas River watershed in the central Peruvian Andes. However, these same households do commonly implement production practices that, according to the climate literature, are likely to build their adaptive capacity and reduce the vulnerability of their agricultural systems and livelihoods. The implications of this central finding are several. First, it suggests that households select and adapt farming practices in response to varied social, economic and environmental stressors, of which climate may not be the most pressing (McDowell and Hess, 2012; Gandure et al., 2013). This interpretation underscores the importance of providing accurate and timely information on current and future climate risks to aid farmers in updating climate beliefs and making informed decisions (UNDP and BCPR, 2013). It also reinforces the notion that many adaptive measures offer net benefits independent of climate change (Smith and Lenhart, 1996). Participatory action research and other "bottom-up" approaches offer a unique set of methods for engaging farmer input to develop adaptation strategies that simultaneously address multiple sources of risk and opportunity in agriculture (Valdivia et al., 2012; Mampufmo et al., 2013; Lee et al., 2015).

The divergence between climate perception and explicit adaptation further suggests that the adoption of some strategies may be more limited by exogenous constraints rather than climate perceptions (Tucker et al., 2010). Our results suggest that information from NGO or government sources, and access to the range of social and natural resources tied to *comunero* membership, are critical factors that support climate adaptation. *Comunero* households are more likely to plant native potato and use irrigation, while households that receive agricultural information from NGO or government sources are more likely to plant trees and adopt soil or water conservation practices. Moreover, farm attributes such as farm size, land ownership, irrigation coverage, soil fertility and agroecology collectively play a major role in determining which strategies farmers adopt. Understanding how these socioeconomic and environmental factors relate to the uptake of adaptive measures can help policymakers to identify critical points for intervention (Nhemachena and Hassan, 2007). In this vein, we conclude that education and extension provide an essential foundation for climate adaptive agriculture, but constraints on access to productive resources must also be addressed.

Our results also point toward a possible tradeoff between efficiency and equity for initiatives that provide training and information to support climate adaptation. Controlling for household, farm and village attributes, *comunero* members are 13.3% more likely to receive information from NGO or government sources, on average, compared to non-*comunero* households (Appendix 3). Targeting educational programs to *comunero* members offers several efficiencies. Entities from outside the community can share information with large numbers of farmers at centralized *comunero* meetings, instead of visiting households one by one. The complexities of building trust and gaining acceptance throughout the community are simplified when NGO or government representatives receive formal approval from a few community leaders. Moreover, *comunero* members may be faster to adopt new technologies due to the various productive resources to which they share access. For example, *comunero* farmers may be more likely to adopt an innovation that increases irrigation efficiency simply because they are more likely to have access to irrigation infrastructure.

If entitlements to draw on communal resources greatly influence adaptive capacity and coping ability, then non-*comunero* households are likely to be more vulnerable to climate change (Smit and Pilifosova, 2001). Thus, programmatic efficiencies may come at a cost to equity if interventions targeting *comunero* households systematically fail to reach the most vulnerable households. Both efficiency and equity are important measures of success for initiatives to promote climate adaptation, and programs should be evaluated accordingly (Adger et al., 2005). Social safety nets and other policies that support households to transition out of agriculture into less risky livelihood activities are critical if and when agricultural adaptation is not plausible for extremely poor or vulnerable households.

APPENDIX 1

Table A2.1

Conscious Adaptation with Original and Winsorized Data (N=240)

VARIABLES	(1) Original data	(2) Winsorized data
Female	0.0271	0.0128
	(0.0495)	(0.0515)
Age	0.00555	0.0220
	(0.0140)	(0.0187)
Age squared	-5.13e-05	-0.000210
	(0.000130)	(0.000182)
Education	0.000141	0.00197
	(0.00630)	(0.00726)
Household size	0.0216**	0.0171
	(0.0109)	(0.0168)
% Members < 5 yrs	-0.00501*	-0.00383
	(0.00302)	(0.00324)
Wealth	-0.00210	-0.00163
	(0.00347)	(0.00508)
Comunero status	0.0581	0.0702
	(0.0671)	(0.0629)
Farm size (ln)	-0.0183	-0.0239
	(0.0251)	(0.0268)
Number of parcels	0.0286**	0.0382
	(0.0146)	(0.0341)
% Land ownership	-0.000311	-9.84e-05
	(0.000564)	(0.000561)
% Fertile farmland	-0.000273	-0.000182
	(0.000487)	(0.000525)
% Irrigation coverage	-0.00205*	-0.00243**
	(0.00107)	(0.00110)
% Low elevation AEZ	0.000984	0.00107*
	(0.000599)	(0.000610)
NGO or government information	0.130*	0.129*
	(0.0682)	(0.0688)
Peer information	-0.0127	-0.0164
	(0.0475)	(0.0472)
Media information	0.278**	0.284**
	(0.111)	(0.115)
Acopalca	0.101	0.140
	(0.115)	(0.122)
Chamisería	-0.0349	-0.0363
	(0.0934)	(0.0960)
Vilcacoto	0.218	0.191
	(0.148)	(0.151)
Cochas Grande	0.0120	0.0126
	(0.0880)	(0.0884)
Cochas Chico	0.0249	0.0101
	(0.0741)	(0.0743)
Observations	240	240
Wald chi-squared	31.91	32.79
P-value	0.0396	0.0649
Pseudo R-squared	0.1920	0.1692

Note. Marginal effects from logit models. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

APPENDIX 2

Table A2.2

Climate Perceptions with Original and Winsorized Data (N=240)

VARIABLES	(1) Original data	(2) Winsorized data
Female	-0.668	-1.022
	(0.882)	(0.892)
Age	0.794***	1.169***
	(0.221)	(0.307)
Age squared	-0.00758***	-0.0116***
	(0.00216)	(0.00307)
Education	0.342***	0.383**
	(0.128)	(0.159)
Household size	-0.221	-0.425
	(0.215)	(0.290)
% Members < 5 yrs	0.0156	0.0331
	(0.0403)	(0.0489)
Wealth	0.0620	0.0610
	(0.0638)	(0.0942)
Comunero status	0.125	0.293
	(1.280)	(1.248)
Farm size (ln)	-0.185	0.00120
	(0.367)	(0.479)
Number of parcels	0.639	0.437
	(0.415)	(0.689)
% Land ownership	-0.000183	0.00319
	(0.0105)	(0.0106)
% Fertile farmland	-0.0225**	-0.0225**
	(0.0101)	(0.0102)
% Irrigation coverage	-0.0237	-0.0268*
	(0.0151)	(0.0154)
% Low elevation AEZ	-0.00908	-0.00869
	(0.0104)	(0.0107)
NGO or government information	1.223	1.357
	(1.192)	(1.181)
Peer information	-8.870***	-8.656***
	(0.992)	(1.031)
Media information	3.209**	2.894*
	(1.548)	(1.597)
Acopalca	-0.661	-1.206
	(1.637)	(1.675)
Chamisería	-0.282	-0.405
	(3.054)	(3.079)
Vilcacoto	-1.158	-1.205
	(1.401)	(1.460)
Cochas Grande	-1.924	-1.861
	(1.497)	(1.514)
Cochas Chico	-3.010**	-3.122**
	(1.303)	(1.347)
Constant	-3.553	-10.70
	(5.653)	(7.913)
Observations	240	240
R-squared	0.399	0.392

Note. Coefficient estimates from OLS. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A2.3

Growing Native Potato with Original and Winsorized Data (N=286)

VARIABLES	(1) Original data	(2) Winsorized data
Female	-0.0324	-0.0439
	(0.0557)	(0.0548)
Age	-0.00549	-0.00987
	(0.0137)	(0.0196)
Age squared	1.65e-05	5.21e-05
	(0.000133)	(0.000197)
Education	0.00174	-0.00190
	(0.00741)	(0.00864)
Household size	-0.0121	-0.0189
	(0.0131)	(0.0189)
% Members < 5 yrs	-0.00269	-0.00298
	(0.00236)	(0.00292)
Wealth	0.000195	0.000678
	(0.00436)	(0.00495)
Comunero status	0.151**	0.160**
	(0.0662)	(0.0670)
Farm size (ln)	-0.0121	-0.00234
	(0.0217)	(0.0283)
Number of parcels	0.0434**	0.0428
	(0.0214)	(0.0385)
% Land ownership	-0.00102	-0.000936
	(0.000655)	(0.000667)
% Fertile farmland	-0.00179***	-0.00177***
	(0.000568)	(0.000582)
% Irrigation coverage	-0.00226**	-0.00240**
	(0.00100)	(0.00104)
% Low elevation AEZ	-0.00127**	-0.00126**
	(0.000585)	(0.000589)
NGO or government information	0.105	0.109
	(0.0825)	(0.0819)
Peer information	-0.222***	-0.218***
	(0.0590)	(0.0617)
Media information	0.0267	0.0386
	(0.109)	(0.107)
Acopalca	0.500***	0.498***
	(0.0298)	(0.0303)
Chamisería	-0.115	-0.123
	(0.114)	(0.114)
Vilcacoto	0.251***	0.244***
	(0.0662)	(0.0671)
Cochas Grande	0.222***	0.221***
	(0.0669)	(0.0657)
Cochas Chico	0.189***	0.188***
	(0.0567)	(0.0579)
Observations	286	286
Log likelihood	-133.36	-133.61
Wald chi-squared	60.29	60.63
P-value	0.0000	0.0000
Pseudo R-squared	0.3176	0.3164

Note. Marginal effects from logit models. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A2.4

Planting Trees with Original and Winsorized Data (N=286)

VARIABLES	(1) Original data	(2) Winsorized data
Female	0.113*	0.106*
	(0.0637)	(0.0627)
Age	-0.000627	0.000445
	(0.0149)	(0.0208)
Age squared	-4.44e-05	-5.65e-05
	(0.000144)	(0.000208)
Education	0.0160**	0.0240***
	(0.00781)	(0.00931)
Household size	0.0166	0.0294
	(0.0133)	(0.0187)
% Members < 5 yrs	-0.00760***	-0.00741**
	(0.00268)	(0.00309)
Wealth	0.00122	-0.00296
	(0.00461)	(0.00594)
Comunero status	-0.00291	0.00903
	(0.0710)	(0.0722)
Farm size (ln)	0.0254	0.0295
	(0.0226)	(0.0301)
Number of parcels	0.0235	0.0441
	(0.0248)	(0.0423)
% Land ownership	0.000270	0.000255
	(0.000686)	(0.000691)
% Fertile farmland	-0.00163***	-0.00157***
	(0.000594)	(0.000592)
% Irrigation coverage	0.000808	0.000811
	(0.000986)	(0.000967)
% Low elevation AEZ	0.00151**	0.00163**
	(0.000667)	(0.000664)
NGO or government information	0.260***	0.262***
	(0.0788)	(0.0778)
Peer information	0.0676	0.0668
	(0.0659)	(0.0660)
Media information	0.174	0.187
	(0.116)	(0.118)
Acopalca	0.387***	0.355***
	(0.0889)	(0.0900)
Chamisería	0.0461	0.0265
	(0.153)	(0.161)
Vilcacoto	0.136	0.121
	(0.105)	(0.106)
Cochas Grande	0.0650	0.0471
	(0.0976)	(0.100)
Cochas Chico	0.148**	0.128*
	(0.0738)	(0.0767)
Observations	286	286
Log likelihood	-163.84	-163.21
Wald chi-squared	57.78	57.06
P-value	0.0001	0.0001
Pseudo R-squared	0.1577	0.1610

Note. Marginal effects from logit models. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A2.5

Irrigation with Original and Winsorized Data (N=286)

VARIABLES	(1) Original data	(2) Winsorized data
Female	0.0234	0.0173
	(0.0566)	(0.0548)
Age	0.00476	0.0173
	(0.0126)	(0.0182)
Age squared	-6.82e-05	-0.000192
	(0.000123)	(0.000181)
Education	-0.00515	-0.00456
	(0.00723)	(0.00871)
Household size	-0.0137	-0.0233
	(0.0126)	(0.0163)
% Members < 5 yrs	0.00110	0.00252
	(0.00249)	(0.00276)
Wealth	-0.00408	-0.00570
	(0.00344)	(0.00507)
Comunero status	0.114*	0.108*
	(0.0636)	(0.0639)
Farm size (ln)	0.0429*	0.0579**
	(0.0236)	(0.0256)
Number of parcels	0.0572	0.108***
	(0.0351)	(0.0364)
% Land ownership	0.00289***	0.00300***
	(0.000483)	(0.000504)
% Fertile farmland	-0.00117*	-0.00114*
	(0.000607)	(0.000584)
% Low elevation AEZ	0.00184***	0.00193***
	(0.000593)	(0.000596)
NGO or government information	0.0501	0.0692
	(0.0687)	(0.0659)
Peer information	-0.000873	-0.0255
	(0.0570)	(0.0594)
Media information	-0.0544	-0.0173
	(0.0867)	(0.0819)
Acopalca	-0.0490	-0.0226
	(0.0965)	(0.0960)
Chamisería	-0.215**	-0.239**
	(0.0974)	(0.0937)
Vilcacoto	-0.0162	-0.0556
	(0.0867)	(0.0807)
Cochas Grande	0.0525	0.0113
	(0.0858)	(0.0822)
Cochas Chico	-0.0156	-0.0420
	(0.0704)	(0.0712)
Observations	286	286
Log likelihood	-142.86	-139.49
Wald chi-squared (df = 21)	60.43	71.63
P-value	0.0000	0.0000
Pseudo R-squared	0.2333	0.2513

Note. Marginal effects from logit models. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A2.6

Soil or Water Conservation with Original and Winsorized Data (N=286)

VARIABLES	(1) Original data	(2) Winsorized data
Female	0.0232	0.0292
	(0.0506)	(0.0524)
Age	0.0248*	0.0213
	(0.0147)	(0.0190)
Age squared	-0.000265*	-0.000229
	(0.000151)	(0.000193)
Education	0.00564	0.0116
	(0.00602)	(0.00777)
Household size	-0.00593	0.00456
	(0.0115)	(0.0154)
% Members < 5 yrs	-0.00163	-0.00270
	(0.00216)	(0.00260)
Wealth	0.00126	0.000719
	(0.00377)	(0.00479)
Comunero status	-0.107	-0.0911
	(0.0704)	(0.0686)
Farm size (ln)	0.00893	-0.000837
	(0.0229)	(0.0278)
Number of parcels	0.00429	0.00672
	(0.0184)	(0.0332)
% Land ownership	-8.24e-05	-0.000150
	(0.000579)	(0.000590)
% Fertile farmland	-0.00111**	-0.00115**
	(0.000537)	(0.000543)
% Irrigation coverage	0.00132*	0.00140*
	(0.000800)	(0.000811)
% Low elevation AEZ	0.000265	0.000282
	(0.000607)	(0.000600)
NGO or government information	0.180**	0.189**
	(0.0783)	(0.0806)
Peer information	-0.0987**	-0.0970**
	(0.0456)	(0.0479)
Media information	0.349***	0.352***
	(0.101)	(0.0992)
Acopalca	-0.0974	-0.104
	(0.0826)	(0.0762)
Chamisería	-0.0286	-0.0354
	(0.114)	(0.117)
Vilcacoto	0.187*	0.204**
	(0.101)	(0.104)
Cochas Grande	0.0109	0.0203
	(0.0799)	(0.0835)
Cochas Chico	0.0875	0.0884
	(0.0706)	(0.0700)
Observations	286	286
Log likelihood	-122.86	-123.52
Wald chi-squared	43.87	46.06
P-value	0.0037	0.0019
Pseudo R-squared	0.1637	0.1593

Note. Marginal effects from logit models. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

APPENDIX 3

Table A2.7

Access to Agricultural Information from Different Sources (N=286)

VARIABLES	(1) NGO or Government	(2) Peer	(3) Media	(4) None
Female	0.0673	0.0161	0.0163	-0.0674
	(0.0539)	(0.0573)	(0.0379)	(0.0641)
Age	0.0188	0.0206	0.0236	-0.0370*
	(0.0147)	(0.0213)	(0.0145)	(0.0219)
Age squared	-0.000209	-0.000203	-0.000232	0.000393*
	(0.000147)	(0.000212)	(0.000146)	(0.000218)
Education	0.0100	-0.000211	-0.00261	0.00707
	(0.00754)	(0.00842)	(0.00609)	(0.00944)
Household size	-0.00539	-0.00690	-0.00931	0.0126
	(0.0113)	(0.0188)	(0.0117)	(0.0193)
% Members < 5 yrs	-0.000627	0.00918***	0.00111	-0.00794**
	(0.00243)	(0.00276)	(0.00234)	(0.00314)
Wealth	-0.00258	-0.00997**	0.00233	0.0124**
	(0.00396)	(0.00491)	(0.00325)	(0.00559)
Comunero status	0.133***	-0.0375	-0.00299	-0.0525
	(0.0404)	(0.0745)	(0.0438)	(0.0729)
Farm size (ln)	0.0150	-0.0325	-0.00270	0.00425
	(0.0237)	(0.0301)	(0.0201)	(0.0320)
Number of parcels	0.0133	0.160***	0.0440	-0.159***
	(0.0324)	(0.0378)	(0.0290)	(0.0418)
Acopalca	0.0634	-0.200***	0.200	0.0804
	(0.0932)	(0.0705)	(0.135)	(0.108)
Chamisería	0.360**	-0.126	0.0277	-0.239
	(0.142)	(0.0998)	(0.114)	(0.150)
Vilcacoto	-0.0910	-0.0779	0.00381	0.150*
	(0.0580)	(0.0697)	(0.0618)	(0.0840)
Cochas Grande	0.0224	-0.131*	0.116	-0.00413
	(0.0637)	(0.0744)	(0.0963)	(0.0984)
Cochas Chico	-0.158***	-0.130**	-0.0112	0.188**
	(0.0536)	(0.0611)	(0.0552)	(0.0732)
Observations	286	286	286	286
Log likelihood	-110.05	-149.35	-69.07	-176.88
Wald chi-squared	43.01	36.23	25.26	35.67
P-value	0.0002	0.0016	0.0466	0.0020
Pseudo R-squared	0.1793	0.1189	0.1094	0.974

Note. Marginal effects from logit models. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

APPENDIX 4

In this appendix we outline an alternative specification using factor analysis to address possible issues of multicollinearity. Factor analysis is not widely used in microeconomic studies. However, it offers distinct benefits for regression analysis with cross-sectional data when explanatory variables are highly correlated and interpretation of coefficient estimates for individual predictors is ambiguous. When multicollinearity is a concern, as in the present study, factor analysis can be applied to reduce the number of explanatory variables to a smaller number of "factors" with more favorable properties for regression analysis. Scott (1966) argues that this statistical method can be a valuable tool in microeconomic analysis:

> Factor analysis has been used very little by economists. Some economists have used the first principal component of factor analysis in the construction of indexes. This is, however, only a small compartment of the whole factor analysis story. Factor analysis appears to be a particularly appropriate tool in the economic field where many "independent'" variables have high intercorrelation and where there are errors in all variables. The problems involved in obtaining meaningful coefficients of regression by the method of least squares with such intercorrelated data are well known.
>
> Stochastic linear equations can be obtained from factor analysis which give better coefficients (better from the standpoint of their economic meaning and theoretic expectation) than do regression equations obtained by traditional least squares. Judging from empirical results, and based upon the factor model, factor analysis accounts for high intercorrelation among the variables and also accounts for errors among all variables rather than just the dependent variable. (p. 552).

We use exploratory factor analysis to identify three latent factors that describe much of the covariance among 13 original explanatory variables representing household and farm characteristics. Unlike Principal Components Analysis, which calculates the components as linear combinations of the original variables, factor analysis defines the original variables as linear combinations of the underlying factors. We first calculate the correlation matrix, taking the Pearson correlation for each pair of continuous variables, the polychoric correlation for each pair of ordinal variables, and the polyserial correlation when one variable is ordinal and the other continuous (Kolenikov and Angeles, 2004). We extract a series of uncorrelated factors from the resulting matrix such that each subsequent factor accounts for a decreasing amount of variance. We perform factor rotation using the varimax technique, which "maximizes the spread of variance across the extracted factors" while maintaining their orthogonal property (Spicer, 2005). This step eases the interpretation of individual factors because it tends to reduce the number of high factor loadings and cause high and low factor loadings to diverge for each factor (Stevens, 2002).

Table A2.8 presents the rotated factor loadings, which represent pairwise correlations between the variables and the factors. Given our sample size of 286 observations, any factor loading with an absolute value greater than 0.303 is considered to be statistically significant at a 1% confidence level (Stevens, 2002). Ten out of thirteen explanatory variables have high factor loadings on one of the first three factors. When deciding how many factors to retain, analysts typically elect to keep factors with Eigenvalues greater than one (Spicer, 2005). In this case, only the first two factors meet this standard. However, we elect to retain the third factor because it shows high factor loadings for three different variables, which is impressive given the small number of variables in the factor analysis. Together these three factors explain 93.9% of the covariance among the explanatory variables.

The first factor is demographic in nature, as high Factor 1 scores are associated with younger, better educated households that have a higher proportion of young children and are less likely to be *comunero* members. Factor 2 is positively associated with farm size, number of parcels and the asset-based wealth index, which are all indicators of a household's asset stock and, therefore, its productive capacity. The third factor pertains to farm ownership and infrastructure, and it is positively associated with irrigation coverage, the percent of land under household ownership and the low-elevation agroecological zone (AEZ).

Table A2.8 also reports the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy for each variable, and for the overall model. The KMO statistic ranges from zero to one, and it indicates the proportion of variance in the variables that might be caused by underlying factors (Dziuban and Shirkey, 1974). Higher values, between 0.8 and 1.0, suggest that the data are well suited to factor analysis, while values below 0.5 indicate that factor analysis is unlikely to produce meaningful results. The overall KMO score of 0.58 is relatively low and suggests that our data may be poorly suited to factor analysis. By repeating the factor analysis on slightly different sets of explanatory variables in a comparative analysis, we were able to achieve a KMO of 0.68, which is mediocre. We continue with the original model, despite the lower KMO score, as our goal is to extract and evaluate factors underlying the original set of explanatory variables in the linear and logistic regression models presented earlier in this paper.

Table A2.9 presents results from a linear regression model predicting the Climate Impact Score (CIS) as a linear combination of the first three factors, information sources and village effects. All three factors are significantly correlated with climate perceptions. Factor 1 is positively associated with CIS, indicating that the younger demographic tends to perceive more and greater damages to agricultural production from climate change. The positive association between Factor 2 and CIS suggests that households with greater productive capacity tend to experience larger negative impacts from climate change. Factor 3 is negatively associated with CIS, indicating that farm ownership, irrigation infrastructure and placement in the low-elevation AEZ tend to mitigate impacts from climate change.

Table A2.10 presents results from independent logistic regression models predicting the likelihood of adoption for the same four climate adaptive production practices that we analyze earlier in the paper. This iteration of the model includes the first three factors from factor analysis in place of the original set of variables representing household and farm characteristics. Interestingly, the first factor is not significantly correlated with any of the four climate adaptive outcomes. Factor 2, representing productive capacity, is positively associated with native potato production, but negatively associated with irrigation. Conversely, Factor 3 is negatively associated with native potato production, but positively associated with irrigation. These results points to the possibility of two different farm typologies, which may be more important than demographic characteristics in explaining the adoption and continued use of native potato varieties and irrigation systems. It appears that larger and more complex farms may be better suited to the uptake of native potato production, while land ownership and location in the low-elevation AEZ tend to support irrigation use. Notably, none of the three factors is significantly associated with the likelihood of tree planting or the likelihood of practices that conserve soil and water. These two adaptive production practices appear to depend more on access to information from extension or media sources, and on residence in Acopalca.

Table A2.8

Factor Analysis of Explanatory Variables (N=286)

Variable	Factor 1	Factor 2	Factor 3	KMO
Age	**-0.748**	0.089	0.082	0.605
% Members < 5 yrs	**0.687**	-0.092	0.008	0.717
Education	**0.516**	0.201	-0.035	0.666
Comunero status	**-0.332**	0.186	0.103	0.527
Number of parcels	-0.024	**0.760**	-0.113	0.589
Farm size (ln)	-0.115	**0.698**	0.132	0.657
Wealth	0.296	**0.366**	-0.009	0.402
% Irrigation coverage	-0.034	-0.101	0.635	0.561
% Land ownership	-0.123	0.283	**0.472**	0.548
% Low elevation AEZ	-0.117	-0.077	**0.326**	0.531
Female	-0.135	-0.059	**0.117**	0.486
Household size	0.171	0.087	-0.031	0.575
% Fertile farmland	-0.027	-0.078	-0.092	0.393
Eigenvalue	1.85	1.55	0.75	
Percent of variance	39.3	34.7	19.9	
Overall KMO				0.581

Note. The Kaiser-Meyer-Olkin measure of sampling adequacy is abbreviated "KMO".

Table A2.9

Perceived Climate Impact with Factor Analysis (N=240)

VARIABLES	(1) Climate Impact Score
F1: Demographic status	0.0880**
	(0.0429)
F2: Farm size and productive assets	0.282***
	(0.0994)
F3: Farm ownership and infrastructure	-0.0576***
	(0.0185)
NGO or government information	1.412
	(1.226)
Peer information	-9.298***
	(0.897)
Media information	3.544**
	(1.520)
Acopalca	-2.567*
	(1.532)
Chamisería	-0.232
	(2.881)
Vilcacoto	-1.356
	(1.322)
Cochas Grande	-1.173
	(1.458)
Cochas Chico	-3.252***
	(1.193)
Constant	19.76***
	(1.238)
Observations	240
R-squared	0.312

Note. Coefficient estimates from OLS. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A2.10

Likelihood of Climate Adaptive Practices with Factor Analysis (N=286)

VARIABLES	(1) Native Potato	(2) Trees	(3) Irrigation	(4) Soil or water conservation
F1: Demographic status	0.00206	0.00241	-0.00331	0.00154
	(0.00253)	(0.00276)	(0.00209)	(0.00218)
F2: Farm size and productive assets	0.0122*	0.00737	-0.0186***	-0.000270
	(0.00646)	(0.00630)	(0.00418)	(0.00502)
F3: Farm ownership and infrastructure	-0.00559***	0.00207	0.0137***	0.00164
	(0.00128)	(0.00132)	(0.000903)	(0.00106)
NGO or government information	0.116	0.297***	0.140*	0.189**
	(0.0763)	(0.0729)	(0.0717)	(0.0802)
Peer information	-0.283***	0.0279	0.0161	-0.127***
	(0.0542)	(0.0630)	(0.0429)	(0.0437)
Media information	0.0902	0.210*	0.132*	0.412***
	(0.102)	(0.113)	(0.0795)	(0.101)
Acopalca	0.495***	0.295***	-0.206***	-0.148**
	(0.0315)	(0.0958)	(0.0441)	(0.0599)
Chamisería	-0.0649	0.0289	-0.253***	-0.0313
	(0.120)	(0.152)	(0.0364)	(0.119)
Vilcacoto	0.262***	0.0825	0.0949	0.161
	(0.0624)	(0.103)	(0.0724)	(0.101)
Cochas Grande	0.246***	0.0356	0.141**	0.0134
	(0.0645)	(0.0962)	(0.0703)	(0.0829)
Cochas Chico	0.229***	0.0978	0.125**	0.0573
	(0.0550)	(0.0740)	(0.0562)	(0.0680)
Observations	286	286	286	286
Wald chi-squared	65.45	27.97	73.30	29.11
P-value	0.0000	0.0033	0.0000	0.0022
Pseudo R-squared	0.2631	0.0776	0.4905	0.1133

Note. Marginal effects from logit models. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

CHAPTER 3

LINKING AGRICULTURAL PRODUCTION AND HOUSEHOLD DIETARY DIVERSITY

3.1 INTRODUCTION

Agriculture is widely regarded as a key driver of economic development for rural areas of developing countries. However, yield increases in production do not always translate into improved nutritional outcomes on the consumption side. This apparent paradox, along with a growing emphasis on nutrition as a priority in developing countries, has inspired a literature that conceptually identifies agriculture-nutrition linkages as a focal point and a key area of research in the pursuit of nutrition-sensitive agricultural practices and policies (Fan and Pandya-Lorch, 2012; Ruel et al., 2013). Among the various pathways linking agriculture and nutrition, two plausible pathways that can be leveraged to improve the nutritional quality of household diets are: (1) increased household incomes generated from agricultural production, and (2) the incorporation of nutrient-dense products into farming systems for home consumption (Haddad, 2000; Arimond et al., 2011; Hoddinott, 2012). However, empirical research addressing the influence of farm production diversity and associated variables on nutritional outcomes is rare (Dillon et al., 2015). This paper uses an agricultural household model to empirically identify relationships and pathways linking agricultural production with household dietary diversity. Specifically, the paper examines the relative importance of a direct production-consumption pathway and an agricultural income pathway in explaining a positive relationship between farm size and dietary diversity. We also explore whether pathways linking agriculture and nutrition differ for households with some commercial crop sales compared to those that devote the entirety of their harvest to home consumption.

Globally, several billion people are considered to be at risk of one or more micronutrient deficiencies, including about 40% of the population in developing countries (Black, 2003; Pinstrup-Andersen, 2007). Micronutrient malnutrition undermines human health and productivity and has been shown to cause permanent damage to the cognitive development of children born to micronutrient-deficient mothers (Welch and Graham, 1999). Each year more than 1.1 million child deaths, representing 11% of annual child mortality worldwide, are estimated to be directly attributed to deficiencies in one of four important micronutrients: vitamin A, zinc, iron and iodine (Black et al., 2008). Also known as "hidden hunger," micronutrient malnutrition comprises one dimension of a "triple burden" of malnutrition, which may occur simultaneously with either of the other two dimensions: undernutrition (inadequate energy intake) and overnutrition (excessive energy intake) (Pinstrup-Anderson, 2007).

While the causes of micronutrient malnutrition are multiple and complex, the variety and composition of food items in an individual's diet have major consequences for that individual's nutritional outcomes (Gómez and Ricketts, 2013). Consequently, increasing the diversity of human diets is an important strategy for improving diet quality and addressing persistent micronutrient deficiencies, particularly among the rural poor in developing countries. Numerous studies across a range of settings have shown dietary diversity to be a good indicator of nutritional status in general (Arimond and Ruel, 2004; Jones et al., 2014a), and of micronutrient adequacy in particular (Kennedy et al., 2007; Moursi et al., 2008; Arimond et al., 2010; Arsenault et al., 2013). Dietary diversification depends on the consistent availability of, and access to, a variety of food items. A food system that supports human nutrition must therefore generate a variety of agricultural outputs from crop and livestock production systems, and also provide the necessary market infrastructure to efficiently link diverse food products with consumers (Pingali, 2015).

There is no general agreement in the academic literature regarding the most appropriate scale for agricultural diversification (Sibhatu et al., 2015). However, an emerging consensus within the international development community points to household- and farm-level diversification of production and livelihood strategies as a guiding principle for nutrition-sensitive agriculture (FAO, 2013). Several recent studies document a significant positive association between farm production diversity and dietary diversity, particularly when access to food in the marketplace is limited or unreliable (Keding et al., 2012; Oyarzun et al., 2013; Jones et al., 2014b; Snapp and Fisher, 2015; Bellon, et al, 2016; Hirvonen and Hoddinott, forthcoming). Beyond improving access to a diverse diet, farm diversification may support additional pathways to nutrition for rural households by bolstering incomes, improving natural resource management, boosting farm productivity, reducing economic and production risk, moderating seasonality and enhancing climate adaptation (Frison et al., 2011; FAO, 2013). Furthermore, some approaches to diversification may also advance women's empowerment by promoting female control of productive assets and income streams, with expected returns to nutrition (Meinzen-Dick, et al, 2012). Agronomists have also stressed the conservation value of maintaining high varietal diversity on individual farms, although the nutritional implications of infraspecific (within-species) diversity are not well understood (Bellon, 1996).

Implicit in studies linking production diversity with dietary diversity is an assumption that agricultural households face imperfect markets for key goods and services, resulting in nonseparability of production and consumption behaviors (Singh et al., 1986, Van Dusen, 2000; Hoddinott et al., 2015). For example, if a farming household's desired food variety is unavailable or economically inaccessible in the marketplace, the household may elect to maintain a more diverse portfolio of crops and livestock for home consumption in order to avoid monotonous diets (Bellon, 1996). Even when consumer markets offer a wide range of food items, high transaction costs may deter market participation. Farmers must evaluate the expected gains from specialized production against the probable increases in transaction costs associated with greater reliance on markets to procure goods for household consumption (Omamo, 1998). This tradeoff implies that improved household access to markets may increase the opportunity cost of farm diversification (de Janvry et al., 1991). Farmers with relatively low transaction costs may achieve more diverse diets by specializing in the production of cash crops and using farm revenues to purchase a varied diet in the marketplace.

The objective of this paper is to evaluate the relationship and underlying mechanisms linking agricultural production and household dietary diversity within the Shullcas River Watershed in the highlands of Peru. Our study contributes to the literature on agricultural-nutrition linkages by grounding the empirical estimation strategy in a conceptual framework based on the traditional agricultural household model. Specifically, we build on Van Dusen and Taylor's (2005) extension of Singh et al.'s (1986) unitary household model by specifying household demand functions for production diversity and dietary diversity under income and market constraints. Using unique cross-sectional production and consumption data from a recent household survey in the Peruvian highlands, we jointly estimate the effects of household and farm characteristics on production diversity and dietary diversity, controlling for variation in market access. We reject a null hypothesis of separability between household production and consumption decisions. After establishing a significant correlation between farm size and dietary diversity, we test whether this relationship can be explained by farm-level production diversity, implying a direct production-consumption linkage, or by farm profitability, implying an indirect income effect. We also test whether the relative importance of these two pathways differs for purely subsistence versus semi-commercial farming households. Our results show a positive association between production diversity and dietary diversity, supporting the presence of a direct production-consumption pathway. Without controlling for the presence of commercial farming, we are unable to reject a null hypothesis of no association between farm profit and dietary diversity. However, limited evidence of an income pathway linking farm revenue to household dietary diversity emerges for households that sell some or all of their crop harvest in the marketplace.

The paper is organized as follows: the next section presents the conceptual framework and outlines the central hypotheses driving this study. Section 3.3 details the empirical estimation strategy, while Section 3.4 describes the study site and our data. We report empirical results in Section 3.5, and Section 3.6 concludes the chapter.

3.2 CONCEPTUAL FRAMEWORK

3.2.1 Agricultural Household Model

We take the household to be the decision-making unit for farm production, where management choices affect crop and livestock diversity, and for household food consumption, where food purchasing and preparation decisions affect dietary diversity. Following Van Dusen's extension (Van Dusen, 2000; Van Dusen and Taylor, 2005) of the traditional agricultural household model (Singh et al., 1986), we define a utility maximization problem subject to income and market constraints. We take X_i to denote household consumption of agricultural products $i = 1, \ldots, I$, which the household may also produce. The household derives utility from consumption of agricultural goods ($\boldsymbol{X}$) and market goods ($\boldsymbol{Z}$), conditional on taste norms defined by a vector of household traits ($\boldsymbol{\Phi}_{HH}$). We define a full income constraint as the sum of farm income, exogenous income ($\bar{Y}$), and a household time endowment (T) valued at the market wage (w). Households decide which of $j = 1, \ldots, J$ agricultural products to produce and the total output of each (Q_j). Farm income is the market value (p) of production less household consumption, net of the cost of purchased inputs. Technological production constraints are embedded in the cost function ($C(\cdot)$) and conditional on a vector of farm attributes ($\boldsymbol{\Phi}_{Farm}$). Market constraints on the consumption of agricultural goods $i = 1, \ldots, I$ are represented by $H_i(\cdot)$ and conditional on market characteristics that affect individual household transaction costs ($\boldsymbol{\Phi}_{Market}$).

$$U = U(\boldsymbol{X}, \boldsymbol{Z}; \boldsymbol{\Phi}_{HH}) \tag{1}$$

$$Z = p(\boldsymbol{Q} - \boldsymbol{X}) - C(\boldsymbol{Q}; \boldsymbol{\Phi}_{Farm}) + \bar{Y} + wT \tag{2}$$

$$H_i(Q_i, X_i; \mathbf{\Phi}_{Market}) = 0 \qquad (3)$$

Constrained maximization of Equation 1 subject to Equations 2 and 3 leads to the following household supply and demand functions:

$$\boldsymbol{Q} = Q_j^C(p, \mathbf{\Phi}_{HH}, \mathbf{\Phi}_{Farm}, \mathbf{\Phi}_{Market}) \qquad (4)$$

$$\boldsymbol{X} = X_i^C(p, Y^c, \mathbf{\Phi}_{HH}, \mathbf{\Phi}_{Farm}, \mathbf{\Phi}_{Market}) \qquad (5)$$

where Q_j^C denotes constrained-optimal production levels of j farm products, X_i^C denotes constrained-optimal consumption levels of i food items, and Y^c represents full income associated with Q_j^C.

We conceptualize the diversity of household farm production and of household food consumption to be outcome variables that do not explicitly enter the utility function as choices, but rather emerge from a household's utility maximization process, subject to constraints. Thus, we model farm production diversity as a derived demand for a given number of agricultural goods produced by the household. Similarly, we represent dietary diversity as the derived demand for a given number of food items consumed by the household. In the constrained case these demand functions take the following form:

$$PD^C = PD(Q_j^C(p, \mathbf{\Phi}_{\boldsymbol{HH}}, \mathbf{\Phi}_{\boldsymbol{Farm}}, \mathbf{\Phi}_{\boldsymbol{Market}})) \qquad (6)$$

$$DD^C = DD(X_i^C(p, Y^c, \mathbf{\Phi}_{\boldsymbol{HH}}, \mathbf{\Phi}_{\boldsymbol{Farm}}, \mathbf{\Phi}_{\boldsymbol{Market}})) \qquad (7)$$

where PD^C denotes household production diversity at the constrained-optimal production level, and DD^C represents household dietary diversity at the constrained-optimal consumption level.

If, contrary to our expectations, transaction costs are zero for all i then the market constraint expressed in Equation 3 drops out of the model. In other words, this model "collapses to the standard agricultural household model presented in Singh et al. (1986) when the constraint is not binding for all i" (Van Dusen and Taylor, 2005). If markets are complete and efficient, then household production and consumption decisions will be recursive, with optimal production levels depending solely on sale prices and farm attributes. This convenient feature of the model allows us to evaluate whether conditions for nonseparability exist within our sample by testing for significant associations between household characteristics and production diversity.

3.2.2 Hypotheses

We use the conceptual model outlined above to test whether there is a direct relationship between agricultural production and dietary diversity at the household level. If such a relationship is present, we expect to see significant associations between farm attributes and dietary diversity. After evaluating our primary hypothesis, we test whether the relationship between agricultural production and dietary diversity can be explained by farm-level production diversity, implying a direct production-consumption linkage, or by farm profit, implying the existence of an agricultural income effect. We also test for differential effects of production diversity and farm profit on dietary diversity for households that sell some or all of their crops in the marketplace versus those that do not. Subsequently, we refer to households that allocate all of their crop production to home consumption as "subsistence" farming households, and we label households that sell some or all of their crops in the marketplace as "commercial" farming households. We recognize that the extent of commercialization and the degree of reliance on agricultural income varies widely among the households we label "commercial." Nevertheless, the binary designation of households as either subsistence or commercial allows us to compare the relative importance of our two pathways of interest for these two subgroups. We anticipate a negative interaction between commercial farming and production diversity if the production-consumption pathway is relatively more important for supporting dietary diversity among subsistence farmers. We further expect a positive interaction between commercial farming and farm profitability if the income pathway is relatively more important for ensuring diverse diets among commercial farming households.

3.3 EMPIRICAL ESTIMATION STRATEGY

3.3.1 Empirical Model

Reduced form equations derived from the demand functions modeled in Equations 6 and 7, respectively, take the following forms:

$$PD_{ab} = \beta_0 + \boldsymbol{\beta_1}\boldsymbol{\Phi}_{\boldsymbol{Farm_a}} + \boldsymbol{\beta_2}\boldsymbol{\Phi}_{\boldsymbol{HH_a}} + \delta_b + \mu_{ab} \tag{8}$$

$$DD_{ab} = \gamma_0 + \boldsymbol{\gamma_1}\boldsymbol{\Phi}_{\boldsymbol{Farm_a}} + \boldsymbol{\gamma_2}\boldsymbol{\Phi}_{\boldsymbol{HH_a}} + \delta_b + \nu_{ab} \tag{9}$$

Production diversity (PD_{ab}) for household a in village b depends on exogenous household traits and farm attributes of household a, and on market characteristics of village b, which are embedded in the village fixed effects (δ_b). Similarly, dietary diversity (DD_{ab}) for household a in village b depends on vectors of exogenous household traits and farm attributes. Dietary diversity also depends on the market characteristics of village b, so we include village fixed effects. Error terms μ_{ab} and ν_{ab} are taken to be independently and identically distributed (i.i.d.), although the error terms for the same household are presumed to be correlated across the two equations.

To evaluate the relationship between agricultural production and dietary diversity, we assess the null hypothesis of no association between farm attributes and dietary diversity (eg. $\boldsymbol{\gamma_1} = 0$). Coefficient estimates significantly different from zero for any farm attribute would contradict the null hypothesis and support our expectation of a direct relationship between agricultural production and dietary diversity at the household level. Furthermore, to formally test for nonseparability between household production and consumption choices, we assess the null hypothesis of no correlation between household characteristics and production diversity (eg. $\boldsymbol{\beta_2} = 0$). Coefficient estimates significantly different from zero for any household characteristic would contradict this null hypothesis and support our expectation of nonseparability for households in our sample (Benjamin, 1992).

3.3.2 Empirical Challenges

Contemporaneous correlation of error term μ_{ab} with ν_{ab} causes several challenges for estimation. Independently modeling production diversity and dietary diversity outcomes would ignore cross-equation error correlation, potentially reducing the precision of our estimates (Hill et al., 2008). To test for contemporaneous correlation we estimate Equations 8 and 9 independently and calculate the correlation between the residual terms from the two equations. In our estimation we use two different indicators of household dietary diversity: Food Consumption Score (FCS) and Household Dietary Diversity Score (HDDS), as described in Section 3.4. Using OLS to independently estimate the two equations with FCS as the outcome variable, we find a significant positive correlation between the residuals ($r = 0.194$, $p = 0.001$), which suggests potential efficiency gains from estimating the two equations jointly. We therefore use Zellner's seemingly unrelated regression (SUR) technique to jointly estimate the correlates of production diversity and FCS, the first indicator of dietary diversity (Zellner, 1962). However, with HDDS as the outcome variable there is no significant correlation between the residuals from Equations 8 and 9 fitted with OLS. The same is true if we use a Poisson distribution, which may be a more appropriate fit for modeling HDDS (Snapp and Fisher, 2015; Hirvonen and Hoddinott, forthcoming). As a result, we expect no loss of efficiency from independent estimation of the correlates of production diversity and HDDS, our second dietary diversity indicator.

The second challenge arises when we consider how to estimate effects of production diversity or farm profitability on dietary diversity. One straightforward approach would be to include production diversity and profitability as explanatory variables in Equation 9 and estimate coefficients using OLS. In fact, this approach is common in recent studies addressing similar research questions (Jones et al., 2014b, Sibhatu et al., 2015; Snapp and Fisher, 2015). However, we know from Equation 8 that PD_{ab} varies with μ_{ab}, which is correlated with ν_{ab}. Given our observation of contemporaneous cross-equation error correlation, it is readily apparent that production diversity would be an endogenous explanatory variable. In other words, unobservable household preferences for a diverse or nutritious diet are likely to impact crop and livestock management decisions, with *de facto* effects on production diversity. Farm profitability is also an outcome of farm management decisions, and may therefore be similarly correlated with unobservable household dietary preferences. As a result, this empirical strategy cannot unequivocally identify specific causal effects of production diversity or farm profitability on dietary diversity. However, significant coefficient estimates on production diversity and farm profitability will provide suggestive evidence in support of these mechanisms as pathways linking agricultural production and dietary diversity.

Alternatively, instrumental variable (IV) estimation can be used to identify the causal effects of an endogenous explanatory variable, producing consistent coefficient estimates if viable instruments can be found. Two recent studies apply IV approaches to address this problem of endogeneity. Dillon et al. (2015) benefit from a panel dataset that includes observations from a post-planting period and post-harvest period for a nationally-representative sample of approximately 5,000 agricultural households in Nigeria. They use data on temperature, rainfall and semi-fixed agricultural capital from the planting season to instrument for production diversity and agricultural revenue. They find statistically significant, albeit small, impacts of production diversity and agricultural revenue on post-harvest dietary diversity. Notably, the coefficients on production diversity and agricultural revenue display a downward bias in preliminary OLS models that fail to address endogeneity. The authors are not confident in their identification of production diversity effects on dietary diversity, as the excluded instruments do not pass the Sargan-Basmann test for overidentification. Furthermore, their selection of total agricultural revenue, rather than net farm profit, as an indicator of agricultural income may be misleading as it does not account for production costs.

Hirvonen and Hoddinott (forthcoming) use a set of village-level instruments, including elevation, temperature and slope, plus an interaction effect between elevation and temperature, to instrument for household-level production diversity in rural Ethiopia. The authors then estimate effects of farm production diversity on an individual dietary diversity score (IDDS) for children age 6 to 59 months. Their results show significant positive effects of production diversity on IDDS, *ceteris paribus*. Similar to Dillon et al. (2015), the coefficient on production diversity is biased downward in preliminary OLS and Poisson models. Standard diagnostic tests indicate that this IV model is well identified.

This recent use of IV estimation shows promise for reducing bias in the identification of causal relationships between agricultural production and dietary diversity at the household level. However, our cross-sectional household survey data come from a relatively small region in the Peruvian highlands, and the dataset does not contain household-level climate data or other variables that would make for especially compelling instruments. To assuage any readers who might be particularly concerned about biased estimates due to violations of the exogeneity assumption, Appendix 5 presents impacts of production diversity on dietary diversity using farm size and farm fragmentation as instruments for production diversity. IV diagnostic tests suggest that these instruments are relevant and that the model is overidentified. However, the ability of our instruments to meet the exclusion restriction requires strong assumptions about missing markets for land rental and purchase. Although historical evidence supports this claim, it cannot be tested in our sample.

The IV approach is not our preferred specification, given its reduced efficiency and our uncertainty about its ability to reduce bias. Instead, we rely on OLS to evaluate effects of production diversity and farm profit on household dietary diversity. Results from Dillon et al. (2015) and Hirvonen and Hoddinott (forthcoming), in addition to results from our own IV estimation in Appendix 5, suggest that OLS coefficient estimates will be biased downward and will therefore provide conservative estimates of the associated effects. Additional robustness checks are performed using alternative specifications listed in Appendix 8 (results not shown).

3.4 STUDY SITE AND DATA

3.4.1 Study Site

The Shullcas River Watershed covers the administrative districts of Huancayo and El Tambo, about 300 km east of Lima, Peru's capital city (Figure 3.1). The watershed lies within the greater Mantaro River Valley that sits between the Eastern and Western Cordilleras of the Peruvian Andes in Junín Region. The Shullcas River originates at the base of the Huaytapallana glacier (4,800 m), and drains an area of over 23,000 hectares before entering the Mantaro River (3,200 m) (PRAA, 2013). The Shullcas River passes through the city of Huancayo, and provides the primary source of water for both agricultural and urban uses throughout its drainage basin. The greater Mantaro River Valley is characterized by a tropical, high-altitude climate, with mean annual temperature around 10°C, and mean annual rainfall of approximately 740 mm, between 1960 and 2002 (IGP, 2005). Temperature follows a diurnal cycle, such that daily variation is greater than seasonal variation. In contrast, precipitation follows a seasonal cycle in which about 40% of annual precipitation occurs during the peak rainy season between January and March (IGP, 2005).

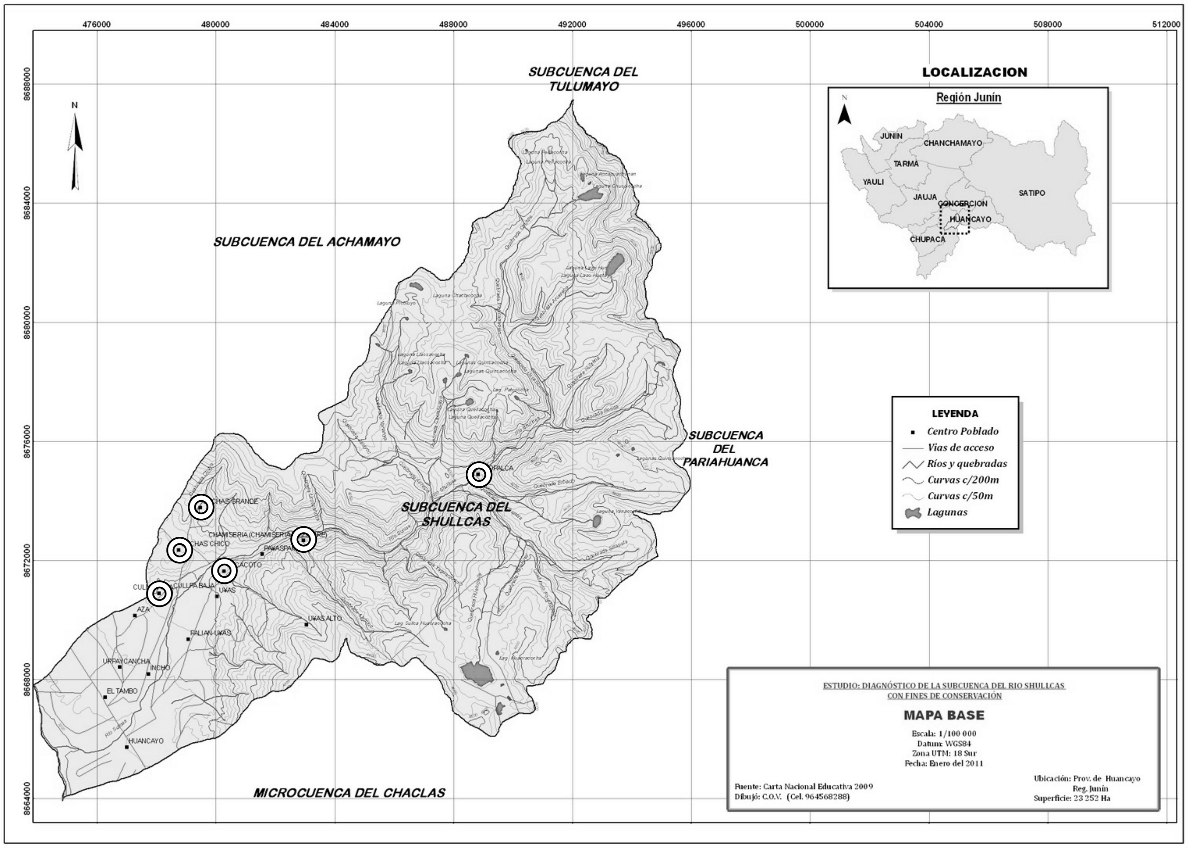

Figure 3.1. Map of the Shullcas River Watershed. The Shullcas River extends from the Huaytapallana glacier along the northeast edge of the watershed to the city of Huancayo and the Mantaro River in the southwest. White circles indicate the locations of the six study villages. The map is adapted from Mapas Temáticos del Peru: http://mapasplanosperu.blogspot.com/2011/02/mapa-de-vegetacion-de-la-subcuenca-del.html

The municipality of Huancayo is highly urbanized, with an estimated 2015 population of 454,757 across seven districts, including just over 278,000 inhabitants in the two districts that comprise the Shullcas River Watershed (Haller and Borsdorf, 2013; INEI, 2013). Despite the degree of urbanization, agriculture persists as a principle livelihood activity in rural and peri-urban farming communities outside the city, where many families continue to rely on traditional agricultural practices to meet subsistence needs. Farmers commonly grow maize, broad bean and modern potato varieties along the valley floor, where plots tend to be flatter and better suited to irrigation, while planting hardier native tuber crops, including *oca*, *olluco* and *mashua*, and numerous varieties of native potato at higher elevations where plots are steeper and daily temperatures are more variable. Wheat, barley and quinoa are also grown in the region. Vegetables, primarily carrots, onions and garlic, made up just 2% of the total planted area across the seven districts that comprise Huancayo Provence in the 2015 growing season (DEIA, 2016). Due to climate extremes, farming households rarely produce crops at elevations above 3,800 m, but they often pasture livestock in this zone. Livestock represent an important source of meat, dairy and fiber in the Andean highlands. Many farmers in the Shullcas River Watershed prefer cattle and sheep to the endemic llama and alpaca. Households frequently keep small livestock, including poultry, *cuy* (guinea pigs) and rabbits, primarily for household consumption.

Over the past decade, Peru has seen substantial improvements across a range of development indicators at the national level (Acosta and Haddad, 2014), yet malnutrition and poverty rates remain high in rural areas. In the Junín Region, 19.8% of children under age five are stunted, and the poverty headcount ratio is 19.5% (INEI, 2015; INEI, 2016a). However, fully 30% of 117 farming households with young children in our study had a stunted child under age five (Wheeler et al., 2017). These data suggest that farming households in our sample exhibit disproportionately high rates of infant and young child chronic malnutrition compared to other households in the region.

3.4.2 Household Survey

The data used in this analysis were collected by CARE Perú and Cornell University as part of a larger study on climate change adaptation and food security. Integrated household production and consumption surveys were conducted by eight trained enumerators in six villages between September and early December 2015. The villages varied in size, population, elevation and distance to major markets in the city of Huancayo (Table 3.1). These particular villages were chosen because they were the most heavily engaged in agriculture within the Shullcas River Watershed.

The survey targeted households that grew field crops in the prior farming season, between September 2014 and September 2015. It also targeted non-farming households with children younger than five years in age, but we exclude these observations from our analysis. Overall, enumerators encountered 526 households in the six villages that met the selection criterion. Of these, 4% declined to participate in the survey. Out of 505 survey responses, we dropped nine observations that failed to meet selection criteria and four observations with incomplete responses. Of the remaining 492 completed surveys, we exclude the 198 non-farming households in this analysis, since this study focuses in part on household agricultural production, as well as seven observations with missing data. Table 3.1 reports the distribution of our final sample of 286 households across the six villages.

Table 3.1

Village Attributes and Survey Participation

Village	Elevation	Distance to Huancayo	2007 Population	2015 Survey Participants
	masl	km	households	households
Acopalca	3,898	18.0	192	35 (33)
Chamisería	3,584	10.5	-	13 (11)
Vilcacoto	3,443	7.5	169	30 (25)
Cochas Grande	3,622	9.8	172	39 (33)
Cochas Chico	3,490	9.0	503	100 (81)
Cullpa Alta	3,365	6.6	287	69 (57)
Total			1,323	286 (240)

Note. Population estimates come from the Instituto Nacional de Estadística e Informática (INEI, 2007). The 2007 population estimate for Acopalca includes residents of Chamisería. The numbers in parentheses indicate the sub-sample of households in that completed the survey module on climate change perceptions.

Participant selection was complicated by the fact that none of the six study villages had a current roster of its residents. We obtained rosters of legally registered community members (*comuneros*) in each village from community leaders, under the assumption that active *comuneros* would comprise the entire population of agricultural households. Enumerators visited all of the *comunero* households in the six villages in our sample and invited their participation in the study. However, we discovered that many households on the *comunero* list had not grown field crops in the prior year, and thus did not qualify as farmers. We also encountered other village residents that farmed but were not registered *comuneros*. Any farming household that we encountered was invited to participate if it resided in one of the six sample villages. To the best of our knowledge, the study sample included a majority of farming households in each village, and was highly representative of agricultural households from the six-village sample.

The household survey was designed to be completed in about an hour, and was conducted in one or two visits to the household. Part 1 was directed to the household member responsible for food purchasing, food preparation and feeding decisions (typically a woman). It gathered data on household dietary diversity using 24-hr and 7-day recall periods. It also included a household roster and questions about livelihood activities, housing characteristics, asset ownership and food purchasing. For households that included a young child, the survey gathered information about child feeding practices, including individual dietary diversity, using a 24-hour recall period. Anthropometric measurements were completed for children between six months and five years of age in participating households; this was done at a later time by trained anthropometrists.

Part 2 of the survey was directed to the person responsible for agricultural production decisions in the household. In some households we found only one agricultural decision maker, while other households had multiple members engaged in farm decision making. If a household's primary farmer was not available to complete the survey, but another household member with knowledge of food production activities was present, we interviewed the secondary agricultural decision maker. Slightly more than half of the households reported that their primary agricultural decision maker was female. Part 2 of the survey recorded detailed production data, including farm size, soil quality, slope, agroecological zone, ownership status and irrigation coverage for each parcel. Respondents provided information on plot-level planting and harvesting, uses of harvested crops, and income from crop sales. The production survey also included modules on climate change perceptions and adaptations, soil and water conservation, social networks, agricultural information sources, and participation in extension activities.

3.4.3 Dependent Variables

We take the sum of crop count and livestock count to be our primary indicator of farm production diversity. Crop count was calculated as the number of different crops planted in the prior growing season (summarized in Table 3.2), while livestock count was calculated as the number of different types of livestock owned by the household at the time of the survey (Table 3.3). Although modern and native potato varieties are all members of the same *Solanum tuberosum* species, we count them as two separate crops due to notable differences in their cultivation and use in Andean production systems. We do not include horses or burros in the livestock count, as they do not represent a food source. We do count dairy cows and other cattle as two separate types of livestock due to the importance of dairy production in the study area.

We use two different dietary diversity indicators in our analysis: Food Consumption Score (FCS) and Household Dietary Diversity Score (HDDS). Following World Food Programme (WFP) guidelines, we calculated FCS as the sum of the weighted frequencies of eight food groups using a 7-day recall period (WFP, 2008). For each food group, we multiplied the number of days the household consumed food items within that group within the previous week by a predetermined weight that reflects the relative nutrient density of that food group. The food groups (weights) were as follows: main staples, including grains and tubers (2); pulses (3); vegetables (1); fruits (1); meat, eggs and fish (4); milk (4); sugar and sweets (0.5); oils and fats (0.5). The total sum of all weights multiplied by seven days in a week produces a maximum possible score of 112. Following FAO guidelines, we calculated the second indicator, HDDS, as the sum of food groups consumed by the household during the previous 24 hours, out of 12 possible groups (Kennedy et al., 2011). Each food group is, in effect, equally weighted. The food groups included: cereals; white roots and tubers; vegetables; fruits; meat; eggs; fish and seafood; legumes, nuts and seeds; milk and dairy; oils and fats; sugar and sweets; spices, condiments and beverages. Thus, FCS and HDDS are both indices of household-level dietary diversity. However, HDDS is commonly interpreted as an indicator of economic access to a diverse diet, while FCS incorporates dietary variety and nutritional quality into a single measure.

Table 3.2

Crop Production

Category	Crops	#	%
Tubers	Modern potato	217	0.76
	Native potato	163	0.57
	Olluco (*Ullucus tuberosus*)	59	0.21
	Mashua (*Tropaeolum tuberosum*)	44	0.15
	Oca (*Oxalis tuberosa*)	27	0.09
Grains	Maize	134	0.47
	Barley	8	0.03
	Quinoa	6	0.02
	Wheat	3	0.01
Legumes	Broad bean	68	0.24
	Peas	12	0.04
	Tarwi (*Lupinus mutabilis*)	5	0.02
Vegetables	Lettuce or spinach	1	0.003
Non-food	Forages	11	0.04
Total Observations		286	1.00

Table 3.3

Livestock Production

Livestock	#	%
Poultry	176	0.62
Guinea pig	165	0.58
Sheep	86	0.30
Dairy cow	73	0.26
Cattle	39	0.14
Pig	32	0.11
Donkey	25	0.09
Horse	16	0.06
Alpaca	9	0.03
Llama	9	0.03
Rabbit	9	0.03
Bee hive	9	0.03
Total Observations	286	1.00

3.4.4 Explanatory Variables

Explanatory variables are classified into three categories, following the model specification above and as described in Table 3.4. We use household traits ($\boldsymbol{\Phi}_{HH}$), farm attributes ($\boldsymbol{\Phi}_{Farm}$) and market characteristics ($\boldsymbol{\Phi}_{Market}$) to explain variation in production diversity.

Table 3.4

Variable Names and Descriptions

VARIABLE NAME	DESCRIPTION
	Dependent Variables
Production Diversity	
Crop count	Total number of crops produced in the previous growing season
Livestock count	Total number of different livestock kept by the household
Total count	Sum of crop count and livestock count
Dietary Diversity	
Food consumption score	Sum of weighted frequencies of 8 food groups eaten in the past 7 days
Household dietary diversity score	Number of 12 food groups eaten in the past 24 hours
	Explanatory Variables
Farm Attributes	
Farm size (ln)	Log of cultivable land area in hectares managed by the household
Number of parcels	Number of cultivable parcels managed by the household
Household Traits	
Wealth	Asset-based wealth index
Female household head	Gender of household head (1 = female, 0 = male)
Age	Age of household head in years
Age squared	Squared age of household head
Education	Years of education for household head
Household size	Total number of household members
% Productive members	Percentage of household members age 14 - 65 years
Market Access	
Village fixed effects	Village dummy variables − base option is Cullpa Alta

Note. Modern potato and traditional potato are counted as two separate crop types. Cow and bull are counted as two separate livestock types. Horses and burros are excluded from the livestock count.

Under a strictly separable household model, socioeconomic characteristics and preferences of the household are hypothesized to affect consumption choices (dietary diversity) but not farm management (production diversity). Thus, significant coefficient estimates for variables representing household characteristics in the regression model explaining production diversity would support our prediction of nonseparability. We include age of the household head, plus a quadratic age term, to test whether older farmers maintain higher levels of production diversity. If older households in our sample prefer traditional crops such as *oca*, *olluco* and *mashua*, which are less readily available in the marketplace, then we expect to see a positive relationship between age and production diversity (Van Dusen and Taylor, 2005). Neither our model nor the literature provides any clear indication of the relationship between age and dietary diversity.

Household size (total number of members) and composition (proportion of productive adult members) are included as indicators of household labor available to undertake a wide range of tasks, including agricultural production and food preparation. Positively signed coefficient estimates are expected on variables representing household size and composition if production activities supporting higher levels of farm diversity − or food preparation activities supporting higher levels of dietary diversity − are intensive in family labor and lack perfect substitutes (e.g. hired labor) (Benjamin, 1992).

Gender is included as a variable that may affect access to productive resources. Although our model controls for cultivable land area, we predict lower production diversity for female-headed households if women face restricted access to other productive assets, such as shared pasture or water resources, relative to men. Both gender and education are included as traits that could affect household dietary preferences. Previous studies provide evidence that female control over income and productive assets can increase household food spending, dietary diversity and child nutritional status (Hoddinott and Hirvonen, 1995; Arimond et al., 2011; Meinzen-Dick et al., 2012; Jones et al., 2014b; Snapp and Fisher, 2015). Thus, female-headed households may have higher dietary diversity scores compared to male-headed households, *ceteris paribus*, due to a relative female preference for nutrition. Households with more education are likely to have better access to nutritional information and a higher ability to implement nutritional recommendations. We therefore predict a positive effect of education, indicated by years of schooling completed by the household head, on dietary diversity.

We use an asset-based index to control for household wealth. Our expectation that wealth positively impacts dietary diversity is consistent with previous theoretical and empirical work indicating that dietary diversity is a normal good (Ruel, 2003). Using Principal Components Analysis (PCA) we derive a continuous, normalized measure of socioeconomic status from factor scores for 41 indicators of housing quality and asset ownership (Vyas and Kumaranayake, 2006). To create this variable, we used all 492 observations from farming and non-farming households in the study to increase sample size and heterogeneity. PCA results are presented in Appendix 6.

We hypothesize that farm attributes affect both farm management (production diversity) and household consumption (dietary diversity). In this category we include indicators of farm size (logged cultivable land area) and farm fragmentation (number of cultivable parcels). The ecological literature indicates that land area and environmental heterogeneity tend to be positively correlated with biodiversity (Bellon, 1996; Benin et al., 2004). Thus, we predict positive coefficient estimates for farm size and fragmentation in the regression equation explaining production diversity. Significant coefficient estimates for variables representing farm size and fragmentation in the regression on dietary diversity will support our expectation of a direct relationship between agricultural production and dietary diversity.

A limitation of our data is a lack of household-level indicators of market access. Household distance from the nearest urban market is commonly used to proxy market access in the development literature (Brush et al., 1992; Benin et al., 2004; Sibhatu et al., 2015; Snapp and Fisher, 2015). Although transportation costs are considered reasonable approximations for farm-to-market transaction costs (Omamo, 1998), our dataset does not include individual household distances to Huancayo markets. However, households in our sample are relatively tightly clustered in their respective villages, and virtually all are situated alongside a road. It follows that the duration and cost of a trip to Huancayo is driven primarily by village characteristics (village distance from Huancayo and the frequency, reliability and price of public transportation). Thus, in all of our specifications, we include village dummy variables to control for village-level variation in market access. We use Cullpa Alta (the closest village to Huancayo) as our base for comparison.

Because the literature suggests that production diversity tends to increase with distance from markets (Omamo, 1998), we might expect to see positive coefficient estimates for all $\boldsymbol{\beta_3}$ parameters (village effects), relative to Cullpa Alta, and we might predict that the size and significance of $\boldsymbol{\beta_3}$ estimates would increase with village distance from Huancayo. However, elevation, temperature and agroecological zone are also highly correlated with distance from Huancayo. The city of Huancayo is situated at the lowest point, which coincides with the warmest zone, in the Shullcas River Watershed. Biophysical factors likely have negative effects on crop diversity with increasing distance from Huancayo, as fewer crops are physiologically suited for higher elevations and colder temperatures. For this reason, although we specify village fixed effects, we are unable to isolate impacts of village-level market characteristics $\boldsymbol{\Phi_{Market_j}}$ on household production diversity or dietary diversity. We also lack household and plot level data on elevation and climate, which would otherwise help to control for these effects.

To explore possible mechanisms relating agricultural production to dietary diversity, we introduce additional explanatory variables in subsequent models. Production diversity, as defined above, is expected to be positively associated with dietary diversity if a direct production-consumption linkage exists. Farm profit, as defined in Equation 10, is expected to be positively associated with dietary diversity if an income effect is present. We also include a dummy variable that equals one for commercial farming households, which sell some or all of their crop production in the market, and zero for subsistence farming households, which sell none of their harvest. Interacting the commercial farming indicator with production diversity and farm profit, respectively, allows us to evaluate whether mechanisms linking production and consumption differ for commercial farming households versus subsistence farming households.

$$\rho_i = \sum_{j=1}^{J} \left[p_{ij} Q_{ij} - (I_{ij} + w L_{ij}) \right] - r H_i \qquad (10)$$

We define farm profits ρ for household i as the total value of crop production for all crops $j = 1, \ldots, J$ produced by the household, less the full economic cost of production. The value of crop production is defined as total quantity produced (Q_{ij}) multiplied by price (p_{ij}). For products sold in the marketplace, p_{ij} equals the sale price for product j reported by household i. However, using a sale price for crops consumed entirely within the household would understate the value of those crops because production of goods for household consumption offsets the purchase of similar goods in the marketplace. Thus, if none of product j was sold by household i, then we set p_{ij} equal to the consumer price for product j. We collected consumer price data in a market survey of Huancayo's central marketplace, *Mercado Mayorista*, during December 2015, within the same timeframe that the household surveys were completed. The economic cost of crop production includes the value of purchased inputs and the opportunity cost of labor and land. We include the crop-level input costs (I_{ij}) reported by each household, and crop-level labor quantity (L_{ij}) valued at a constant wage rate (w) equal to the average daily wage of 30 PEN (approximately \$9.25 USD) for the Huancayo region. We include the economic cost of land at the farm level by multiplying the total cultivable land area (H_i) by a constant price representing the typical rental rate for the study area (r) equal to 1,000 PEN per hectare per season (approximately \$310 USD).[1]

[1] Our farm profit indicator is calculated with a constant per-hectare opportunity cost for land. However, it may be unrealistic to assume that all households would be able to rent their land if they so desired, or that all cultivable land in the study area would be equally valued by renters. Thus, using a fixed opportunity cost for land may result in the

3.4.5 *Summary Statistics*

Table 3.5 summarizes household traits for the full sample and for sample subgroups comprised of subsistence and commercial farming households, respectively. Overall, 30% of households had female household heads, and the mean head of household age was 48 years. Mean household size was 4.6 members, of which 65%, on average, were productive members between 14 and 65 years in age. There was no significant difference in the proportion of households led by a female head of household, or in mean age, household size or household composition, between the subsistence and commercial farming subgroups. Mean educational attainment of the household head was 8.1 years. Commercial farming households reported 1.4 more years of education for the household head compared to subsistence farming households, a significant difference at a 5% confidence level. Households with crop sales were also slightly wealthier than subsistence farming households.

Among all sample households, the average cultivable land area in the prior growing season was a quarter hectare (2,500 square meters). However, the distribution of land was highly skewed, with a median land area of 500 square meters. Only 13 households, representing 4.5% of the total sample, managed one hectare or more of farmland. Differences between subsistence and commercial farming households are more evident when comparing farm characteristics. Mean farm size for households with crop sales was more than 4 times larger than mean farm size for households with no crop sales, a difference significant at a 1% confidence level. Commercial farming households also managed significantly more parcels, on average, compared to subsistence farming households.

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overestimation of total costs and the underestimation of farm profits for some farms. Measurement error in our farm profit indicator may bias the evaluation of a potential income pathway linking production and dietary diversity.

Table 3.5

Summary Statistics

	Total Sample	Sample Subgroups: Subsistence Farms	Sample Subgroups: Commercial Farms		
Observations	286	218	68		
		Percentage		Z-stat	
Female household head	0.30	0.31	0.26	0.676	
Female off-farm income	0.49	0.50	0.46	0.561	
Male off-farm income	0.80	0.82	0.74	1.693	
No off-farm income	0.08	0.07	0.10	1.287	
		Mean (SD)		T-stat	
Wealth index	-0.19 (0.98)	-0.24 (1.00)	-0.01 (0.86)	1.688	*
Age	47.8 (15.1)	47.8 (15.1)	47.8 (15.2)	0.012	
Age squared	2513 (1524)	2513 (1540)	2513 (1481)	0.003	
Education	8.11 (4.25)	7.78 (4.32)	9.18 (3.84)	2.392	**
Household size	4.61 (2.20)	4.70 (2.23)	4.32 (2.08)	1.242	
% Productive adult members	0.65 (0.25)	0.65 (0.26)	0.68 (0.25)	0.956	
Farm size (ha)	0.25 (0.96)	0.14 (0.48)	0.61 (1.72)	3.599	***
Log farm size (ha)	-2.82 (1.43)	-3.08 (1.28)	-1.98 (1.58)	5.858	***
Number of parcels	1.94 (1.51)	1.76 (1.10)	2.53 (2.30)	3.773	***
Tropical livestock units	1.92 (7.93)	1.95 (8.87)	1.84 (3.56)	0.096	
Crop diversity	2.65 (1.56)	2.51 (1.34)	3.10 (2.06)	2.773	***
Livestock diversity	2.12 (1.57)	2.01 (1.57)	2.47 (1.53)	2.104	**
Total production diversity	4.77 (2.40)	4.52 (2.24)	5.57 (2.73)	3.196	***
Monthly per-capita food spending (PEN)	194 (158)	187 (160)	218 (148)	1.443	
Food consumption score (FCS)	76.0 (17.7)	75.9 (17.8)	76.4 (17.6)	0.208	
Household dietary diversity score (HDDS)	9.03 (1.38)	8.94 (1.41)	9.29 (1.25)	1.831	*
Total production value ($1,000 USD)	0.71 (0.90)	0.60 (0.77)	1.06 (1.17)	3.700	***
Total production cost ($1,000 USD)	0.51 (0.64)	0.42 (0.37)	0.80 (1.10)	4.327	***
Farm profit ($1,000 USD)	0.20 (0.85)	0.18 (0.78)	0.26 (1.05)	0.644	

Note. *** p<0.01, ** p<0.05, * p<0.1; $1 USD = 3.24 PEN.

Crop count ranged from one to nine out of fifteen total crops recorded in the study area, while livestock count ranged from zero to ten out of ten possible types. Mean household crop count was 2.65, and mean household livestock count was 2.12, resulting in a mean total production diversity of 4.77. Total production diversity among sample households ranged from one to 14 out of a maximum possible score of 25. Commercial farming households had significantly greater crop diversity, livestock diversity, and total diversity compared to subsistence farming households. The distributions of all three production diversity indicators were skewed to the right (Figure 3.2).

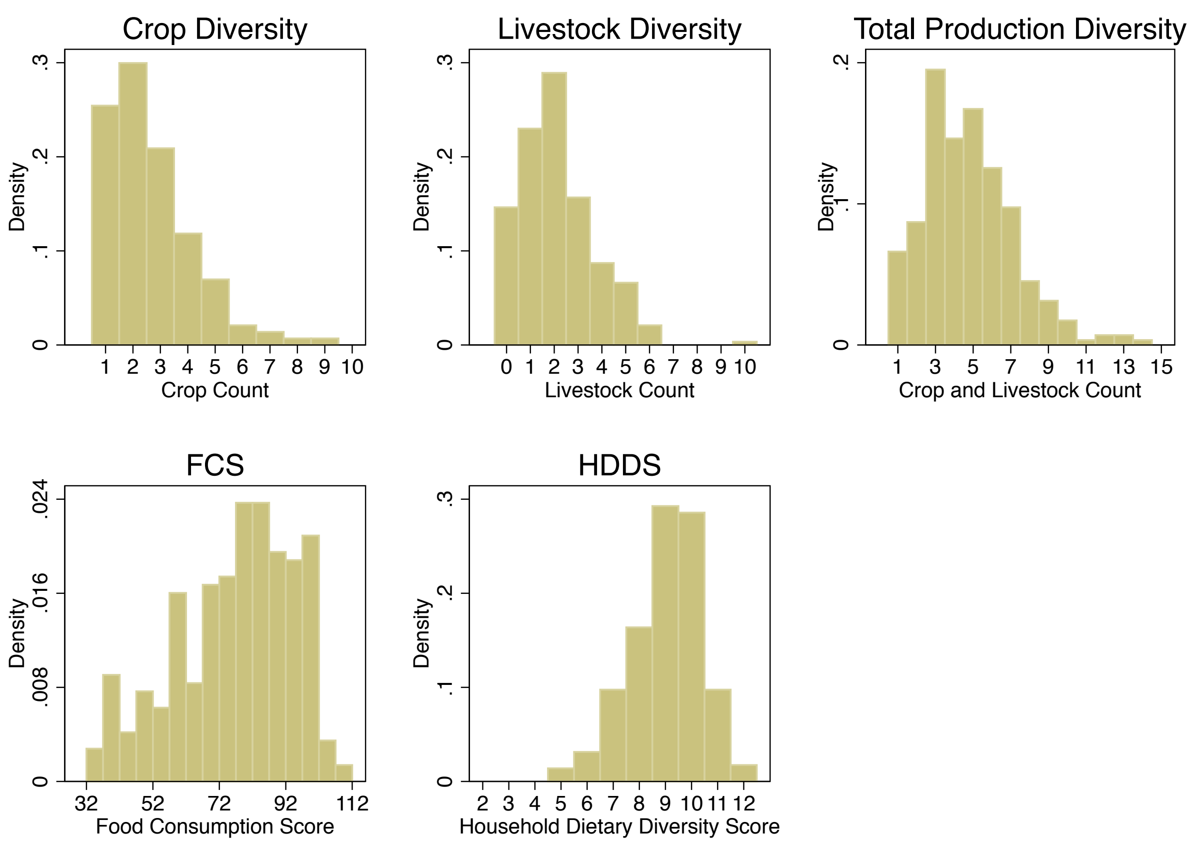

Figure 3.2. Sample distributions of production diversity and dietary diversity indicators.

Mean monthly per-capita food spending among all households was 194 PEN ($60 USD). Commercial farming households spent, on average, 31 PEN ($9.57 USD) more per person per month than subsistence farming households, but this difference was not significant at a 10% confidence level. Peru's Instituto Nacional de Estadística e Informática (INEI) calculates the annual market value of a representative *canasta básica alimentaria*, or basic food basket, which indicates the minimum per capita monthly food expense necessary for a socially acceptable and nutritionally adequate diet (INEI, 2016b). In our sample, 56% of all households spent less than the 2015 value of Peru's *canasta básica alimentaria* (basic food basket), which was 169 PEN ($52 USD) per person per month. Such a high proportion of households with low food spending highlights the importance of auto-consumption of homegrown agricultural goods, as well as the relatively low food prices in Huancayo. Based on food prices that we collected through a market survey in December 2015, we estimate the cost of the standard *canasta básica alimentaria* to be between 135 and 145 PEN ($42 to $45 USD) per person per month in Huancayo. For comparison, 41% of households in our sample reported spending less than 135 PEN per person per month on food.

Observed FCS values ranged from 32 to 112, with a mean of 76 points; only one household achieved the maximum score of 112. For samples such as ours, in which virtually all households consume fat and sugar almost daily, the WFP recommends cutoffs of 28 and 42 points, respectively, to represent "poor" and "borderline" food consumption levels (WFP, 2008). Based on these thresholds, no households in our sample had poor diets, but 17 households, representing 6% of our sample, had diets classified as borderline, or potentially inadequate. In a separate paper, we show through multivariate OLS regression analysis that FCS is positively associated with individual dietary diversity scores (IDDS) and with reduced likelihood of stunting for children aged six months to five years (Wheeler et al., 2017). Sample values for HDDS ranged from 5 to 12, with 57% of households receiving a score of 9 or 10. While there are no standard cutoff points for HDDS, observed values for our sample are high compared to scores reported for rural areas in Africa and South Asia (Kennedy et al., 2010). FCS and HDDS were significantly positively associated with each other ($r = 0.612$, $p < 0.001$) and the distributions of both dietary diversity variables were skewed to the left (Figure 3.2).

Analysis of variance shows that both HDDS and FCS vary significantly by wealth quintile (Table 3.6). Allowing for unequal variances across quintiles, the fourth and fifth quintiles have significantly higher HDDS and FCS, respectively, compared to the first quintile. The fifth quintile also has significantly higher FCS than the second and third quintiles. These data confirm our expectation that dietary diversity is a normal good for households in our sample.

Table 3.6

Household Dietary Diversity by Wealth Quintile

	Wealth Quintile						
	1	2	3	4	5	F-stat	
Food Consumption Score	68.2^{a}	$72.7^{a,b}$	$74.7^{a,b}$	$81.1^{b,c}$	83.7^{c}	8.30	***
Household Dietary Diversity Score	8.53^{a}	$8.81^{a,b}$	$9.00^{a,b}$	9.29^{b}	9.43^{b}	4.33	***

Note. Means with the same superscript letter are not significantly different. *** p<0.01, ** p<0.05, * p<0.1

Table 3.7 illustrates the breakdown, by wealth quintile, of consumption rates for the twelve food groups that comprise HDDS, and of consumption frequencies for the eight food groups that comprise FCS. Considering household diets over the previous 24 hours, we find an increase of more than ten percentage points in the consumption of items form the vegetable and fruit categories, and of more than twenty percentage points in the consumption of items from the meat and dairy categories, for households in the wealthiest quintile compared to the poorest quintile. Analysis of variance shows no significant difference in the frequency of consumption over the prior seven days for starchy staples, legumes, sweets and fats according to wealth quintile. However, wealthy households consumed vegetables, fruits, meat products (including eggs and fish) and dairy products significantly more often than poor households. These findings suggest that variation in household consumption of these four nutrient-dense food groups − fruits, vegetables, meat and dairy − explains much of the overall variation in the two dietary diversity indices presented in Table 3.6.

Table 3.7

Food Group Consumption Rates and Frequencies by Wealth Quintile

Proportion of households that ate foods in each of the 12 HDDS food groups in the past 24 hours						
	Wealth Quintile					Difference between 1st and 5th quintiles
	1	2	3	4	5	
Cereals	1.00	1.00	0.98	1.00	1.00	0.00
White tubers	0.93	0.97	1.00	1.00	1.00	0.07
Legumes	0.36	0.32	0.36	0.31	0.33	-0.03
Vegetables	0.86	0.95	0.92	0.95	0.98	**0.12**
Fruits	0.73	0.69	0.85	0.88	0.88	**0.15**
Meat	0.47	0.51	0.68	0.69	0.74	**0.27**
Eggs	0.51	0.63	0.46	0.56	0.48	-0.03
Fish	0.14	0.17	0.14	0.15	0.21	0.07
Dairy	0.56	0.61	0.66	0.76	0.81	**0.25**
Sugar and sweets	1.00	1.00	1.00	1.00	1.00	0.00
Oils and fats	0.97	0.97	0.98	0.98	1.00	0.03
Condiments	1.00	1.00	0.98	1.00	1.00	0.00
Mean number of days that households ate foods in each of the 8 FCS food groups in the past 7 days						
	Wealth Quintile					
	1	2	3	4	5	F-stat
Main staples	7.00^{a}	7.00^{a}	7.00^{a}	7.00^{a}	7.00^{a}	0.00
Legumes	1.95^{a}	1.88^{a}	1.68^{a}	1.90^{a}	1.95^{a}	0.30
Vegetables	6.12^{a}	6.19^{a}	$6.25^{a,b}$	6.69^{b}	6.72^{b}	2.61 **
Fruits	$3.75^{a,b}$	3.61^{a}	$4.88^{b,c}$	4.98^{c}	5.43^{c}	7.77 ***
Meat, eggs and fish	4.98^{a}	$5.58^{a,b}$	$5.49^{a,b}$	6.12^{b}	6.19^{b}	4.34 ***
Dairy	2.95^{a}	$3.49^{a,b}$	$3.90^{a,b,c}$	$4.59^{b,c}$	5.03^{c}	6.44 ***
Sugar and sweets	6.83^{a}	7.00^{a}	7.00^{a}	6.90^{a}	6.79^{a}	0.99
Oils and fats	6.59^{a}	6.95^{a}	6.85^{a}	6.76^{a}	6.81^{a}	1.21

Note. Bolded numbers indicate a difference of at least 10 percentage points between the 1st and 5th quintiles. Mean values with the same superscript letter are not significantly different. *** p<0.01, ** p<0.05, * p<0.1.

3.5 RESULTS

3.5.1 Correlates of Production Diversity

Table 3.8 presents results using SUR to jointly estimate Equations 8 and 9 due to contemporaneous correlation of the two error terms, with FCS as the measure of dietary diversity. As expected, production diversity increases significantly with farm size and farm fragmentation. The magnitude of these effects is relatively small: a 10% increase in farm size raises production diversity by 0.06 units, while adding an additional parcel raises production diversity by 0.2 units. These results are consistent with other empirical work demonstrating the positive effects of farm size and fragmentation on production diversity (Benin et al., 2004; Van Dusen and Taylor, 2005; Snapp and Fisher, 2015).

There was no evidence of any effect of gender, education, household size or household composition on total production diversity. This result is consistent with the separable agricultural household model (Benjamin, 1992). However, age of the household head has a significant positive and nonlinear association with production diversity. Production diversity increases with age until age 65, which is consistent with other reports that older farmers maintain a greater diversity of crops or varieties (Van Dusen and Taylor, 2005). However, production diversity decreases with age when the household head is more than 65 years old.

The significant coefficient estimate on age contradicts the null hypothesis of separable production and consumption choices (Benjamin, 1992). Under strict separability, household attributes do not affect farm management decisions that determine production diversity. A significant association between age and production diversity implies imperfect markets that disproportionately affect households based on age (Omamo, 1998; Van Dusen and Taylor, 2005). We can imagine several plausible explanations for this phenomenon. Perhaps there are missing markets for traditional crops that older households prefer. The costs of transacting in the marketplace might be higher for older households, and older farmers may be differentially affected by imperfect credit or contingency markets. Whatever the reason, our data lead us to reject the separability hypothesis and to accept the alternative that agricultural households in our sample face imperfect market conditions leading to nonseparable production and consumption choices.

Table 3.8

SUR Joint Estimation of Production Diversity and FCS

VARIABLES	(1) Production Diversity	(2) Dietary Diversity (FCS)
Farm area (ln)	0.605***	1.387*
	(0.104)	(0.797)
Number of parcels	0.210**	-0.0356
	(0.0969)	(0.740)
Wealth	-0.209	3.653***
	(0.154)	(1.174)
Female household head	-0.331	-0.0603
	(0.286)	(2.182)
Age	0.169***	-0.550
	(0.0616)	(0.471)
Age squared	-0.00170***	0.00361
	(0.000620)	(0.00474)
Education	-0.00454	0.517*
	(0.0357)	(0.273)
Household size	0.0149	1.095**
	(0.0610)	(0.466)
% Productive adults (14 - 65 y)	-0.347	1.994
	(0.557)	(4.252)
Constant	1.863	85.41***
	(1.463)	(11.18)
Village fixed effects	Y	Y
Observations	286	286
R-squared	0.278	0.223

Note. Coefficient estimates from seemingly unrelated regressions (SUR) model. Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.

3.5.2 Correlates of Dietary Diversity

As described above, our study uses two standard indicators of household dietary diversity: the Food Consumption Score (FCS) and the Household Dietary Diversity Score (HDDS). We estimate correlates of FCS jointly with correlates of production diversity using SUR estimation to improve efficiency (Table 3.8). Evidence suggests that joint estimation of production diversity and HDDS will not improve efficiency, so we present independent estimation of HDDS fitted with OLS and Poisson models, respectively, in Table 3.9. In the regressions on HDDS, coefficient estimates from OLS are consistent with marginal effects from the Poisson regression. For empirical simplicity we use OLS to fit additional HDDS regression models in the subsequent analysis.

Wealth has a significant positive effect on FCS and HDDS, which is consistent with the classification of dietary diversity as a normal good. This result implies that, holding all else equal, household dietary diversity increases with household income. However, this does not necessarily indicate the presence of an *agricultural* income effect because the vast majority of households in our study generate income through one or more off-farm work opportunities (Table 3.5). As expected, education and household size also have positive and significant coefficient estimates. One additional year of education for the household head is projected to increase FCS by 0.5 points and HDDS by 0.04 points, while an additional household member increases FCS by 1 point and HDDS by 0.1 points. Negative coefficient estimates for age of the household head were significant only for HDDS, suggesting that a one-year increase in age reduces HDDS by 0.07 points. There is no evidence that any other household attributes have significant associations with either of the two dietary diversity indices.

Controlling for wealth and other household and village characteristics, dietary diversity increases with farm size. Significant positive coefficient estimates for farm size in regressions on both FCS and HDDS support our central hypothesis that there is a direct link between agricultural production and household food consumption. For a household that doubles its cultivable land area, a task that is not unthinkable in a region with a median farm size of 500 square meters, the model predicts a 1.4 point increase in FCS, and a 1.5 point increase in HDDS. Contrary to our expectations, there was no evidence of any significant effect of farm fragmentation (number of parcels) on dietary diversity. However, the pairwise correlation between the variables representing farm size and farm fragmentation is strong and highly significant ($r = 0.5087, p < 0.0001$). Thus, the farm size variable may pick up some of the effects of farm fragmentation, and, consequently, it most likely represents farm complexity or heterogeneity in addition to farm area.

Table 3.9

Independent Estimation of HDDS Using OLS and Poisson Regression

VARIABLES	Dietary Diversity (HDDS)	
	(1)	(2)
	OLS	Poisson
Farm area (ln)	0.152**	0.151**
	(0.0624)	(0.061)
Number of parcels	-0.0452	-0.0452
	(0.0656)	(0.0631)
Wealth	0.159*	0.157*
	(0.0926)	(0.0896)
Female household head	0.131	0.119
	(0.176)	(0.175)
Age	-0.0727*	-0.0700*
	(0.0372)	(0.0362)
Age squared	0.000570	0.000540
	(0.000378)	(0.00037)
Education	0.0400*	0.0398*
	(0.0210)	(0.0205)
Household size	0.106***	0.106***
	(0.0385)	(0.0373)
% Productive adults (14 - 65 y)	0.106	0.117
	(0.358)	(0.362)
Constant	10.70***	
	(0.895)	
Village fixed effects	Y	Y
Observations	286	286
R-squared	0.163	
Wald statistic		57.13
P-value		0.0000
Log pseudolikelihood		-604.64

Note. Coefficient estimates from OLS regression and marginal effects from Poisson regression. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

3.5.3 Mechanisms and Interactions

We consider production diversity and farm profit as two possible mechanisms that might explain the relationship between farm size and household dietary diversity. A positive association between farm production diversity and dietary diversity would support the existence of a direct production-consumption pathway, while a positive association between farm profit and dietary diversity would support the presence of an agricultural income pathway linking production and consumption.

We extend this analysis one step further by also considering whether the importance of these two mechanisms might differ depending on whether or not a household sells its own agricultural products in the marketplace. We create a dummy variable for commercial farming such that households with any commercial crop sales receive a "1" and households with no commercial crop sales receive a "0". Thus, by definition, commercial households have some income from their own agricultural activities, while subsistence households have none. A negative interaction between farm production diversity and the commercial farming indicator would suggest that the production-consumption pathway is relatively more important for *subsistence* farming households. Conversely, a positive interaction between farm profit and commercial farming would suggest that an agricultural income effect is relatively more important for *commercial* farming households.

Before evaluating these two pathways, it is useful to examine the relationship between farm size and each of the two proposed mechanisms. Previous results indicate that production diversity is positively associated with farm size. A simple bivariate linear regression analysis suggests that the positive relationship between farm size and production diversity is consistent for subgroups comprised of subsistence and commercial farming households, respectively (Figure 3.3). Two-way linear prediction plots in Figure 3.4 indicate a positive relationship between farm size and total production costs, and between farm size and total production value, which is true for both the subsistence and commercial subgroups. However, there is no evidence of any significant relationship between farm size and farm profit, or between farm size and farm productivity (per-hectare farm profit). Indeed, there is a wide body of literature that documents negative relationships between farm size and farm productivity, although the underlying mechanism is still debated (Bevis and Barrett, 2016). Because production diversity increases with farm size, while farm profit does not, it appears more likely that production diversity could explain the relationship between farm size and dietary diversity.

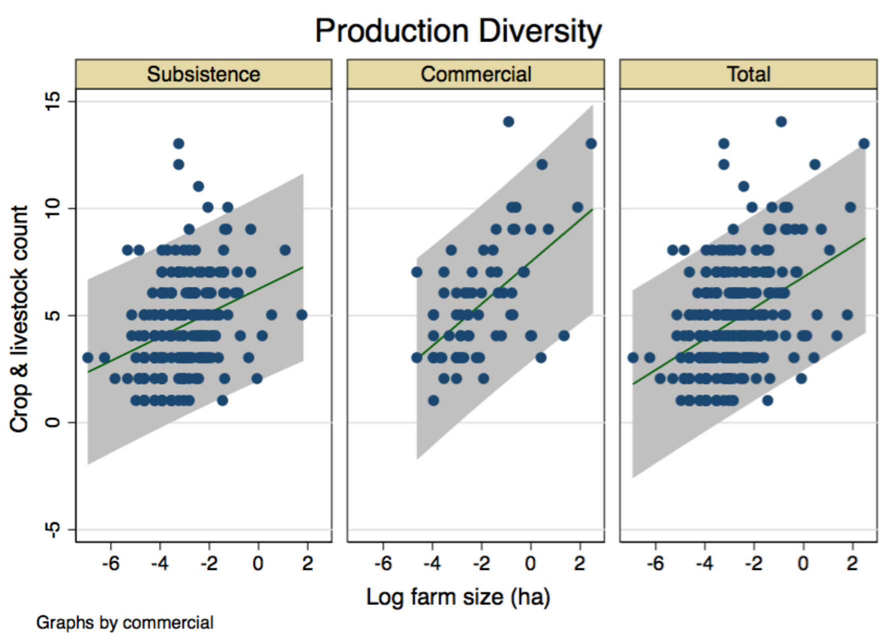

Figure 3.3. Two-way linear prediction of total production diversity. Blue points represent individual observations; the green line represents the forecast; the shaded grey area represents a 95% confidence interval of the forecast. Separate forecasts are shown for subsistence farming households (no crop sales), commercial farming households and the total sample.

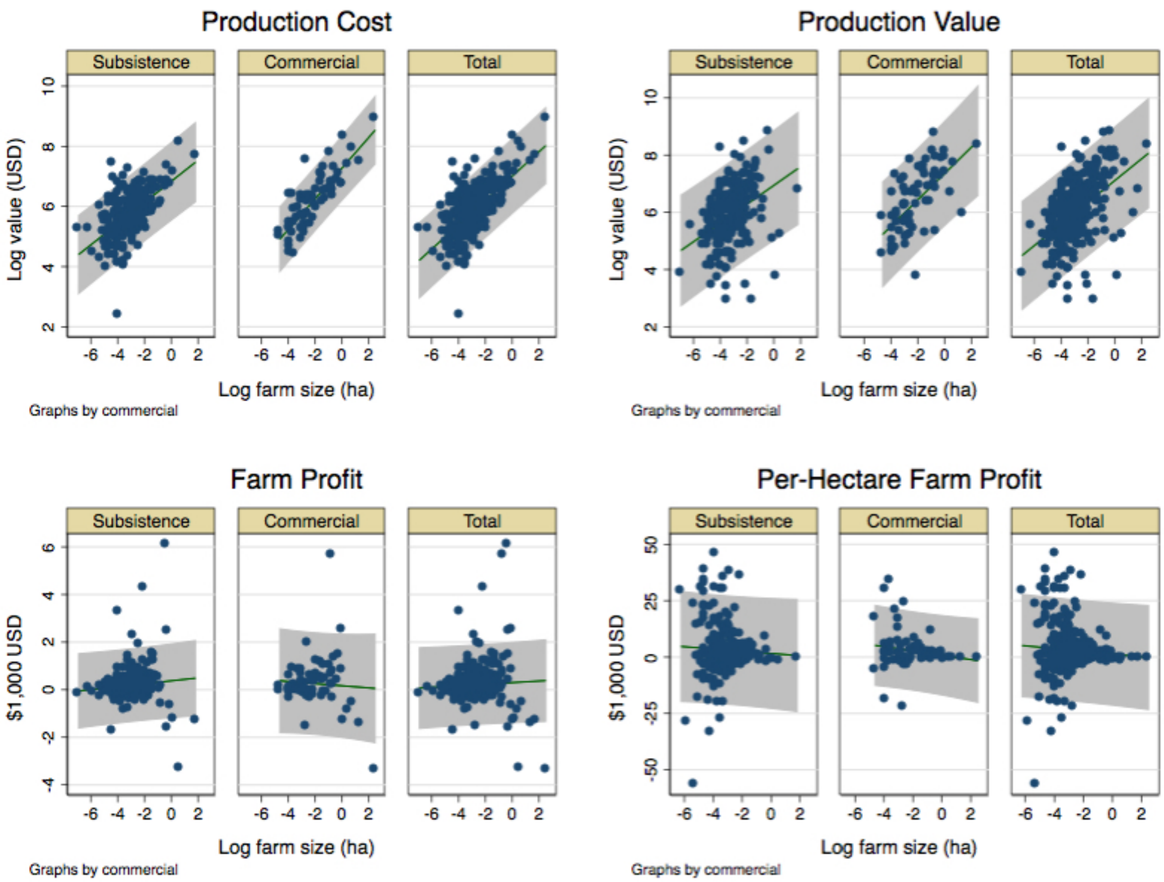

Figure 3.4. Two-way linear predictions of production cost, value, profit and productivity. Blue points represent individual observations; the green line represents the forecast; the shaded grey area represents a 95% confidence interval of the forecast. For each production outcome a forecast is given for subsistence farming households (no crop sales), commercial farming households and the total sample. Farm profit is calculated as production value less production cost. Per-hectare farm profit is an indicator of farm productivity. These values reflect crop production only, costs and revenues from livestock production are not included.

Using FCS as the dietary diversity indicator, Table 3.10 presents associations between dietary diversity and the two proposed mechanisms, while Table 3.11 includes interactions between the two mechanisms and the commercial farming indicator. In the second column of

Table 3.10 there is a significant positive coefficient estimate on production diversity, while the coefficient estimate on farm size is insignificant. This finding suggests that production diversity completely explains the relationship between farm size and FCS. The coefficient estimate on farm profit in the third column is positive, but not significant. Therefore, we cannot reject a null hypothesis of no association between farm profit and FCS. In Table 3.11, the coefficient estimate for the interaction between production diversity and commercial farming is negative but insignificant at a 10% confidence level. The coefficient estimate for the interaction between farm profits and commercial farming is positive but also insignificant. Therefore, although the signs on both interaction terms are as expected, we do not have evidence to reject the null hypothesis of no difference in the effects of production diversity or farm profits on FCS for subsistence versus commercial farming households.

Table 3.10

Possible Mechanisms Explaining FCS

VARIABLES	Food Consumption Score		
	(1)	(2)	(3)
Production diversity		1.440***	
		(0.446)	
Farm profits			0.583
			(0.972)
Farm area (ln)	1.387*	0.515	1.279*
	(0.708)	(0.829)	(0.733)
Number of parcels	-0.0356	-0.338	-0.230
	(0.519)	(0.592)	(0.679)
Constant	85.41***	82.73***	83.52***
	(11.15)	(11.39)	(11.13)
Household covariates	Y	Y	Y
Village fixed effects	Y	Y	Y
Observations	286	286	282
R-squared	0.223	0.251	0.220

Note. Coefficient estimates from OLS. Robust standard errors in parentheses. Household covariates not shown to save space. *** p<0.01, ** p<0.05, * p<0.1.

Table 3.11

Interactions with Commercial Farming to Explain FCS

	Food Consumption Score		
VARIABLES	(1)	(2)	(3)
Production diversity		1.691***	
		(0.500)	
Production diversity * Commercial		-0.790	
		(0.801)	
Farm profits			-0.336
			(0.928)
Farm profits * Commercial			2.626
			(2.163)
Commercial (1 = any crop sales)	-2.556	1.025	-2.996
	(2.341)	(4.667)	(2.366)
Farm area (ln)	1.622**	0.858	1.690**
	(0.730)	(0.827)	(0.798)
Number of parcels	0.0180	-0.208	-0.401
	(0.532)	(0.607)	(0.766)
Constant	86.63***	83.15***	86.20***
	(10.95)	(11.17)	(11.09)
Household covariates	Y	Y	Y
Village fixed effects	Y	Y	Y
Observations	286	286	282
R-squared	0.226	0.257	0.226

Note. Coefficient estimates from OLS. Robust standard errors in parentheses. Household covariates not shown to save space. *** p<0.01, ** p<0.05, * p<0.1.

Results of this same analysis are slightly different with HDDS as the dietary diversity indicator. Coefficient estimates for production diversity and farm profit in Table 3.12 are positive but insignificant. Neither of these two variables explains the positive relationship between farm size and HDDS. However, when controlling for the interaction between production diversity and commercial farming in Table 3.13, there are significant positive coefficient estimates for the variables representing production diversity and commercial farming. Yet the negative coefficient estimate for the interaction between production diversity and commercial farming is not significant at a 10% confidence level. Thus, production diversity is positively associated with HDDS when controlling for commercial farming, and there is no evidence of any difference in the association between production diversity and HDDS for subsistence versus commercial farming households. Furthermore, the coefficient estimate on farm profit in the third column of Table 3.13 is not significantly different from zero when controlling for commercial farming. However, there is a significant positive interaction between commercial farming and farm profit. This result suggests that farm profit is positively associated with HDDS, but only for commercial farming households.

Table 3.12

Possible Mechanisms Explaining HDDS

	Household Dietary Diversity Score		
VARIABLES	(1)	(2)	(3)
Production diversity		0.0441	
		(0.0356)	
Farm profits			0.0345
			(0.0925)
Farm area (ln)	0.152**	0.125*	0.152**
	(0.0624)	(0.0678)	(0.0658)
Number of parcels	-0.0452	-0.0544	-0.104
	(0.0656)	(0.0685)	(0.0726)
Constant	10.70***	10.62***	10.86***
	(0.895)	(0.899)	(0.918)
Household covariates	Y	Y	Y
Village fixed effects	Y	Y	Y
Observations	286	286	282
R-squared	0.163	0.167	0.159

Note. Coefficient estimates from OLS. Robust standard errors in parentheses. Household covariates not shown to save space. *** p<0.01, ** p<0.05, * p<0.1.

Table 3.13

Interactions with Commercial Farming to Explain HDDS

	Household Dietary Diversity Score		
VARIABLES	(1)	(2)	(3)
Production diversity		0.0687*	
		(0.0387)	
Production diversity * Commercial		-0.0968	
		(0.0668)	
Farm profits			-0.0877
			(0.0698)
Farm profits * Commercial			0.341**
			(0.165)
Commercial (1 = any crop sales)	0.183	0.664*	0.106
	(0.181)	(0.383)	(0.187)
Farm area (ln)	0.135**	0.121*	0.159**
	(0.0633)	(0.0660)	(0.0679)
Number of parcels	-0.0490	-0.0485	-0.136*
	(0.0656)	(0.0687)	(0.0772)
Constant	10.62***	10.43***	10.97***
	(0.901)	(0.916)	(0.933)
Household covariates[1]	Y	Y	Y
Village fixed effects	Y	Y	Y
Observations	286	286	282
R-squared	0.166	0.175	0.171

Note. Coefficient estimates from OLS. Robust standard errors in parentheses. Household covariates not shown to save space. *** p<0.01, ** p<0.05, * p<0.1.

To summarize, our results thus far provide strong evidence of a direct pathway linking farm production diversity and household dietary diversity. Yet, evidence of an agricultural income pathway is weak. Thus, although wealth is positively associated with dietary diversity, this effect appears to be driven by off-farm income rather than income from household crop sales. Moreover, results do not show any interaction between farm production diversity and commercial farming status, yet there is some evidence of a positive interaction between farm profit and commercial farming. This suggests that the direct production-consumption linkage is equally important for the subsistence and commercial subgroups, and that there may also be an agricultural income pathway linking food production and household nutrition, but only for households with crop sales.

The relatively slim evidence of any interaction between each mechanism and the commercial farming indicator may reflect the relatively broad classification of households with any agricultural income into the commercial farming subgroup. In fact, on average, households in the commercial farming subgroup report that just 34.4% of their annual household income is generated through the sale of their own crops. Only 24 households, representing 8.4% of the total sample and 35.3% of the commercial farming subgroup, report that they derive at least half of their income from household crop production. This smaller group of households might be a better representation of what true commercial agriculture looks like in our study area, yet the number of observations is too small for meaningful regression analysis.

For a better understanding of how production diversity is related to the consumption of individual food groups, we examine pairwise correlations between farm production diversity and food consumption frequency of eight FCS food groups over a 7-day recall period, disaggregated by wealth (Table 3.14). Across the entire sample, production diversity is positively correlated with the consumption frequency of legumes and dairy products. However, in the bottom wealth quintile, production diversity is positively correlated with consumption frequency of legumes, vegetables, meat products and dairy products. Thus, production diversity is positively associated with consumption of nutrient-dense food groups, particularly among the poorest households.

By contrast, we see very few significant correlations between farm profit and food group consumption frequencies (Table 3.15). Across the entire sample, farm profit was significantly correlated with the consumption frequency of just one food group: legumes. This association appears to be driven by a strong positive association between farm profit and legume consumption frequency among households in the fourth wealth quintile. The dearth of significant associations between farm profit and food group consumption frequency is consistent with results from our multivariate analysis, which provided no evidence of any significant relationship between farm profit and FCS.

Table 3.14

Correlation Between Production Diversity and Consumption Frequency by Wealth Quintile

FCS Food Groups	Wealth Quintile 1		2		3		4		5		Total	
Main staples												
Legumes	0.341	***	0.311	**	0.216	*	0.173		0.356	***	0.255	***
Vegetables	0.268	**	-0.063		0.113		-0.020		0.100		0.091	
Fruits	0.205		-0.147		0.050		-0.193		-0.173		-0.028	
Meat, eggs and fish	0.228	*	0.183		-0.047		-0.067		-0.101		0.060	
Dairy	0.313	**	0.231	*	0.209		0.156		0.198		0.224	***
Sugar and sweets	0.085						0.150		-0.149		0.028	
Oils and fats	0.178		0.219	*	-0.305	**	0.117		0.068		0.071	

Note. Blank spaces indicate homogeneous consumption frequency for a particular food group and sub-sample.
*** p<0.01, ** p<0.05, * p<0.1.

Table 3.15

Correlation Between Farm Profit and Consumption Frequency by Wealth Quintile

FCS Food Groups	Wealth Quintile 1		2		3		4		5		Total	
Main staples												
Legumes	0.048		0.043		0.054		0.404	***	0.009		0.123	**
Vegetables	0.052		-0.164		0.093		-0.134		-0.093		0.001	
Fruits	-0.083		-0.051		0.131		-0.113		-0.059		0.003	
Meat, eggs and fish	0.082		-0.021		0.079		0.152		0.034		0.067	
Dairy	-0.083		0.101		0.068		-0.194		0.081		-0.014	
Sugar and sweets	0.025						-0.158		0.079		-0.011	
Oils and fats	0.038		0.031		-0.326	**	-0.040		-0.052		-0.077	

Note. Blank spaces indicate homogeneous consumption frequency for a particular food group and sub-sample.
*** p<0.01, ** p<0.05, * p<0.1.

3.6 CONCLUSIONS

This paper uses a nonseparable agricultural household model to empirically evaluate the relationship between agricultural production and food consumption. Results show that farm size is significantly positively correlated with both production diversity and dietary diversity. Production diversity also increases with age of the household head, which provides evidence of the nonseparablility of production and consumption choices for households in our sample, despite the relative proximity of Huancayo's urban markets (Benjamin, 1992; LaFave and Thomas, 2016).

The current literature identifies agricultural income growth and farm diversification as two mechanisms with high potential to link agricultural production with improved dietary quality and nutritional outcomes. For the households in our sample, production diversity appears to completely explain the positive relationship between farm size and FCS (Food Consumption Score). This relationship does not hold for the second indicator of dietary diversity, HDDS (Household Dietary Diversity Score), although a significant positive association between production diversity and HDDS is present when we control for the interaction between production diversity and commercial farming. Positive associations between production diversity and FCS in Tables 3.10 and 3.11 provide strong evidence of a direct production-consumption pathway for agricultural households, regardless of whether or not they sell their crops in the marketplace. This finding is not entirely surprising, given that a majority of commercial farming households store a portion of their harvest for home consumption throughout the year. Pairwise correlation analysis in Table 3.14 confirms that production diversity is associated with increased consumption frequency of nutrient-dense food groups, particularly among the poorest households.

Dietary diversity is positively associated with wealth, a pattern we expect to see for normal goods. Yet, we find no evidence of any *agricultural* income effect driving the relationship between farm size and FCS. Weak evidence of an agricultural income pathway linking agricultural production and HDDS does emerge in Table 3.13, but only for the subgroup of households with crop sales. We infer that off-farm income is more important than agricultural income as a driver of household food purchasing decisions in our study area. Because household diets do rely heavily on purchased foods, off-farm income represents a critical pathway to ensure dietary diversity and food security for farming households.

Stronger evidence of an income pathway is expected for commercial farming households in our study area. Yet it is possible that total household income, which is a key determinant of food purchasing and consumption choices, is not highly correlated with agricultural revenues. While we lack the household income data necessary to conclusively evaluate this relationship, we can explore how the net value of agricultural production relates to household food spending. In our sample, average monthly food spending was significantly positively correlated with wealth ($r = 0.188,\ p = 0.002$) but not with farm profit ($r = -0.008,\ p = 0.900$). Additional research into the determinants of food spending, particularly for households engaged in diverse livelihood activities, could help to further explain this result. In particular, it would be interesting to test whether and how control of agricultural income varies by gender, as female control of agricultural assets and corresponding revenues is thought to have positive impacts on dietary quality (Meinzen-Dick et al., 2012).

Although our model cannot identify direct causal effects of farm size on dietary patterns, the positive association between farm size and dietary diversity raises serious concerns in a region where average farm size is extremely small and may be shrinking.[2] In the peri-urban region surrounding Huancayo, farmers face increasing competition from other urban land uses, particularly for prime agricultural land at the valley floor (Haller, 2014). Within this context, the potential of agricultural interventions to achieve significant dietary or nutritional outcomes may

[2] FAO data indicate declining average farm size across a number of developing countries from the 1970's until today, yet data from Peru are not included in this analysis (IFPRI, 2013). Anecdotal evidence suggests that farms in the Andean highlands typically diminish in size over time as land is divided between multiple children in successive generations.

be constrained by small agricultural landholdings.

From a policy perspective, improving welfare and nutrition for smallholder agricultural households likely requires that subsistence farming households make a transition into profitable market-oriented farming or into other non-farming economic activities. Policy actions that improve the commercial viability of smallholder farms are expected to strengthen the income pathway linking agricultural production and dietary diversity. A recent IFPRI report highlights several policy objectives for advancing this goal: improve risk mitigation and climate change adaptation, promote pro-smallholder value chains, and increase smallholder-friendly financing and investment (Fan et al., 2013). Policies that reduce the costs of transacting in markets for agricultural products and services, including markets for credit, contingency and land, are critical for the commercial success of smallholder farmers.

Beyond these interventions, households facing hard constraints to production − such as marginal lands, harsh environmental conditions or extremely small landholdings − may be better off pursuing non-agricultural livelihoods (Fan et al., 2013). This suggestion would hardly surprise farming households in our study area, 92% of which report having one or more sources of off-farm income. Successfully transitioning large numbers of farming households from subsistence agriculture to non-agricultural employment requires investment in vocational training, job placement and social safety nets.

However, emphasizing off-farm employment does not imply that there is no place for nutrition-sensitive agriculture in areas where farmers are making that transition. Indeed, our results indicate that farm-level diversification, especially that which incorporates nutrient-dense products for home consumption, is likely to improve the diversity and nutritional quality of household diets, even when market access is moderately high. This approach could be especially advantageous for the poorest households, who report lower consumption levels of meat products, dairy products and vegetables. More research into time allocation of male and female household members is needed to identify specific production strategies that can be managed efficiently by households in which one or more members pursue off-farm employment.

This study focuses on production diversity and farm revenue as indicators of two distinct pathways with potential to link agriculture and nutrition. However, it does not directly address the possibility of feedback effects between production diversity and farm revenue. In the climate change literature, farm diversification is regarded as a means to reduce the risk of crop failure under increasing climate uncertainty (Perez et al., 2010). Future research, ideally based on repeated observations of the same farming households across multiple growing seasons, is needed to test this assumption. Does the diversification of agricultural products increase a farm's expected net revenue, particularly in a context of increasing climate risk? Could increasing farm profits lead to further diversification, or further specialization, of farming systems? Although it is difficult to identify such dynamic effects with a cross-sectional dataset, empirical research addressing these questions is critical to understanding how the relationships between farm production diversity, household food security and family and child nutrition might evolve over time and in response to increasing impacts of climate change on agriculture.

APPENDIX 5

Instrumental variable (IV) estimation offers a feasible alternative to identify the effects of an endogenous regressor, and it produces consistent coefficient estimates if a viable instrument can be found. A good instrument must be strongly correlated with both the endogenous explanatory variable (production diversity) and the endogenous dependent variable (dietary diversity), conditional on the covariates. However, it must only affect dietary diversity indirectly, through its impact on production diversity. Finally, it must not be correlated with unobservable household characteristics that affect the dietary diversity outcome.

Spatially referenced farm-level temperature and precipitation data could be ideal for instrumenting production diversity (Hirvonen and Hoddinott, forthcoming). Average rainfall, average temperature, and annual maximum and minimum temperatures are likely to impact production diversity, but any effect on dietary diversity would probably be indirect. Furthermore, weather and climate conditions are unlikely to be correlated with unobservable household dietary preferences. In lieu of this data, household or farm altitude could be a good proxy for climate indicators in our study area. However, we have no georeferenced data for the individual households in our sample, nor do we have access to household-level climate data.

We propose farm size and farm fragmentation as plausible instruments. First we consider their relevance. Simple pairwise correlation analysis shows that both farm size and farm fragmentation are positively and significantly correlated with both of the endogenous variables. In multivariate regression analysis, farm size is significantly positively associated with production diversity and dietary diversity, conditional on wealth, other household characteristics and village effects. However, conditional on the same covariates, farm fragmentation is significantly associated with production diversity but not with dietary diversity. Therefore, farm size is unambiguously relevant, while the relevance of farm fragmentation is uncertain. We retain both variables as instruments so that the IV model is overidentified, and we test their joint relevance when estimating the model.

Next we consider whether the two instruments are exogenous to dietary diversity. In the presence of fully functional markets for land rental and sale, it would be difficult to argue that farm size and farm fragmentation were not associated with unobservable household dietary preferences. For instance, a household that prefers a greater variety of food items might be motivated to increase farm size or add a parcel in a different agroecological zone in order to cultivate a greater number of crops. However, we argue that Peru's top-down agrarian reform of the 1970's resulted in a distribution of farmland that is exogenous to dietary preferences in the current period.

Beginning in 1969, a progressive military government enacted a sweeping agrarian reform over the course of a decade, redistributing roughly half of Peru's agricultural land to one third of its rural households (Saleth, 1991). In the Andean highlands this reform abolished the *hacienda* (estate) system whereby "service tenants" worked without pay, often for absentee landowners, in a form of debt bondage. The agrarian reform picked up speed in the mid-1970's as the military expropriated large tracts of agricultural land from *hacienda* owners. The military transferred the major productive resources of each estate to the collective ownership of its former laborers and tenants. In addition, individual families received rights to farmland, allocated based on to their respective relationships with the former *haciendas*. However, titles were not issued to individual families, thereby precluding future land sales. For this reason, land usage rights typically transferred to heirs within the same family or reverted to the community. Additional legislation during the reform period abolished indirect forms of land tenancy and use, including leasing and sharecropping. Unlike the land reform in neighboring Chile, Peru's agrarian reform was not reversed by a subsequent political regime after it ended in 1978.

Based on this history, we argue that farm size and farm fragmentation both meet the exclusion restriction. It is important to note that we define farm size as the log of total cultivable area, including fallow land, managed by the household in the prior farming season. Farm fragmentation is similarly defined as the total number of cultivable parcels managed by the household. By using total cultivable area, rather than total planted area, we dissociate farm size from contemporaneous household planting decisions. Our reduced form equations for IV estimation take the following form:

$$PD_{ab} = \pi_0 + \boldsymbol{\pi_1 IV_\alpha} + \boldsymbol{\pi_2 \Phi_{HH_a}} + \pi_4 Y_a + \delta_b + \mu_{ab} \tag{A}$$

$$DD_{ab} = \gamma_0 + \gamma_1 PD_{ab} + \boldsymbol{\gamma_2 \Phi_{HH_a}} + \gamma_4 Y_a + \delta_b + \nu_{ab} \tag{B}$$

where Equation A is the first stage regression and the instruments (IV_a) are farm size and farm fragmentation, which are excluded from Equation B. We estimate models for FCS and HDDS using the `ivreg2` command with robust standard errors in Stata version 14.1. We also estimate models for HDDS using the `ivpoisson` command. A significant positive coefficient estimate for γ_1 will support our hypothesis that, *ceteris paribus*, dietary diversity increases with production diversity.

Table A3.1 presents effects of production diversity on dietary diversity (FCS), controlling for wealth, household attributes and village effects. The first column shows OLS estimates, while the second and third columns present results of IV estimation using farm size and farm fragmentation to instrument production diversity. Column two presents results using the two-stage least squares (2SLS) estimation procedure, while column three presents results using the two-step efficient generalized method of moments (GMM) estimator. All three models reveal a significant positive effect of production diversity on dietary diversity. The GMM estimator is more efficient than the 2SLS estimator, but less efficient than OLS, yet its coefficient estimate on production diversity is very similar to the result from OLS. Both OLS and GMM estimates indicate that a 1-unit increase in production diversity raises FCS by 1.5 points. Effects of other explanatory variables under IV estimation do not notably differ from OLS estimation. First stage results from the IV estimation are not shown. Test statistics indicate that the model is identified, and the identification is not weak. These results provide strong evidence that, *ceteris paribus*, increases in production diversity translate into gains in dietary diversity for farming households in our sample. Results from Table A3.2 show a similar pattern for effects of production diversity on HDDS, using both linear and Poisson regression models.

Table A3.1

Instrumented Effects of Production Diversity on FCS

VARIABLES	Food Consumption Score (1) OLS	(2) Linear IV (2SLS)	(3) Linear IV (GMM)
Production diversity	1.500***	1.775**	1.564**
	(0.375)	(0.846)	(0.794)
Wealth rank	3.991***	3.999***	3.926***
	(1.381)	(1.348)	(1.344)
Female household head	0.355	0.460	0.534
	(2.214)	(2.115)	(2.112)
Age	-0.778*	-0.824*	-0.796*
	(0.443)	(0.452)	(0.451)
Age squared	0.00594	0.00635	0.00599
	(0.00434)	(0.00437)	(0.00435)
Education	0.526*	0.520*	0.505*
	(0.294)	(0.290)	(0.289)
Household size	1.061**	1.047**	1.058**
	(0.486)	(0.472)	(0.472)
% Productive members (14 - 65 y)	2.887	2.780	2.764
	(4.108)	(4.051)	(4.051)
Constant	79.87***	80.06***	80.68***
	(10.72)	(10.56)	(10.52)
Observations	286	286	286
R-squared	0.249	0.248	0.249
Underidentification test			
Kleibergen-Paap rk LM statistic	-	22.44	22.44
-- P-value	-	0.0000	0.0000
Weak identification test			
Cragg-Donald Wald F statistic	-	29.83	29.83
Overidentification test			
Hansen J statistic	-	0.5220	0.5220
-- P-value	-	0.4701	0.4701

Note. Coefficient estimates from (1) OLS regression, (2) linear IV estimation using two-stage least squares (2SLS), and (3) linear IV estimation using the generalized method of moments (GMM). Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A3.2

Instrumented Effects of Production Diversity on HDDS

	Household Dietary Diversity Score			
VARIABLES	(1) OLS	(2) Poisson	(3) Linear-IV (GMM)	(2) Poisson-IV (GMM)
Production diversity	0.0638**	0.0630**	0.146*	0.150*
	(0.0318)	(0.0308)	(0.0854)	(0.0907)
Wealth rank	0.184**	0.183**	0.185**	0.179**
	(0.0908)	(0.0882)	(0.0903)	(0.0904)
Female household head	0.135	0.126	0.179	0.164
	(0.176)	(0.174)	(0.172)	(0.178)
Age	-0.0788**	-0.0761**	-0.0859**	-0.0845**
	(0.0359)	(0.0348)	(0.0357)	(0.0372)
Age squared	0.000643*	0.000613*	0.000696**	0.000671*
	(0.000359)	(0.000350)	(0.000350)	(0.000365)
Education	0.0416**	0.0416**	0.0400*	0.0408*
	(0.0208)	(0.0203)	(0.0210)	(0.0210)
Household size	0.104***	0.104***	0.0922***	0.939**
	(0.0361)	(0.0349)	(0.0353)	(0.0364)
% Productive members (14 - 65 y)	0.226	0.237	0.159	0.189
	(0.352)	(0.356)	(0.347)	(0.375)
Constant	9.967***		9.944***	
	(0.790)		(0.779)	
Village fixed effects	Y	Y	Y	Y
Observations	286	286	286	286
R-squared	0.153	-	-	-
Pearson's goodness of fit test	-	51.62	-	-
P-value	-	1.00	-	-
Underidentification test				
Kleibergen-Paap rk LM statistic	-	-	22.443	-
-- P-value	-	-	0.0000	-
Weak identification test				
Cragg-Donald Wald F statistic	-	-	29.83	-
Overidentification test				
Hansen J statistic	-	-	1.740	2.157
-- P-value	-	-	0.187	0.142

Note. Coefficient estimates from (1) OLS regression and (3) linear IV estimation. Marginal effects from (2) Poisson regression and (4) IV Poisson estimation. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

APPENDIX 6

Table A3.3

Principal Components Analysis (PCA) Results (N = 492)

Category	Variable Description	Type	Mean	SD	First Factor Score
Housing	Electricity	dummy	0.927	0.261	-0.1329
	Number of bedrooms	continuous	2.467	1.290	0.1329
	Distance to water (minutes)	continuous	0.548	1.917	-0.1558
Water source	Running water in the house	dummy	0.812	0.391	0.2255
	Running water outside the house	dummy	0.096	0.295	-0.1119
	Well/canal/ditch	dummy	0.039	0.193	-0.1303
	River/pond/spring	dummy	0.043	0.203	-0.1235
	Relative/neighbor	dummy	0.010	0.101	-0.0490
Floor material	Wood or ceramic tile	dummy	0.051	0.220	-0.0436
	Cement	dummy	0.407	0.492	0.2831
	Earth or stone	dummy	0.542	0.499	-0.2599
Wall material	Brick with cement	dummy	0.140	0.348	0.2103
	Brick	dummy	0.098	0.297	0.1573
	Adobe/*tapia* with cement	dummy	0.018	0.134	-0.0016
	Adobe/*tapia*	dummy	0.728	0.446	-0.2708
	Stone	dummy	0.012	0.110	0.0099
	Other	dummy	0.004	0.064	-0.0003
Roof material	Wood	dummy	0.002	0.045	0.0051
	Cement	dummy	0.201	0.401	0.2841
	Metal	dummy	0.169	0.375	-0.0761
	Terra cotta tile	dummy	0.622	0.485	-0.1725
	Straw	dummy	0.002	0.045	-0.0491
Bathroom type	Connected to public sewer	dummy	0.295	0.456	0.1751
	Septic system	dummy	0.079	0.270	0.0033
	Latrine	dummy	0.504	0.500	-0.0250
	None	dummy	0.120	0.325	-0.2100
Kitchen	Gas stove	dummy	0.407	0.492	0.2687
	Improved wood stove	dummy	0.091	0.289	-0.0101
	Traditional wood stove	dummy	0.502	0.501	-0.2582
Durable assets	Radio	dummy	0.872	0.334	0.0305
	Television	dummy	0.848	0.360	0.2143
	Cell phone	dummy	0.795	0.404	0.1895
	Fixed phone	dummy	0.049	0.216	0.0555
	Computer	dummy	0.116	0.320	0.1449
	Refrigerator	dummy	0.134	0.341	0.1582
	Blender	dummy	0.551	0.498	0.2200
	Sewing machine	dummy	0.100	0.300	0.0854
	Bicycle	dummy	0.215	0.412	0.0893
	Motorcycle	dummy	0.051	0.220	0.0742
	Car or truck	dummy	0.077	0.267	0.1228
	Tractor	dummy	0.008	0.090	0.0353

APPENDIX 7

Table A3.4 presents OLS results for Equation 8 using three different indicators of production diversity (crop count, livestock count and total count). This analysis is useful for comparing determinants of crop versus livestock diversity and evaluating their aggregate effects on total production diversity. Gender has a significant effect on livestock diversity, as the presence of a female head of household reduces the livestock count by 0.367, on average. This finding suggests that male-headed households have access to a greater variety of productive livestock, or other resources that support livestock diversity, than do female-headed households. Presence of a female head of household is positively associated with crop count, although this relationship is not statistically significant. Household size was negatively associated with crop count, but positively associated with livestock count, at a weak ($p < 0.10$) level of significance. The proportion of productive members in the household was also weakly negatively associated with crop diversity. Together these finding suggest that livestock diversity is positively associated with household labor availability, but crop diversity is not. Coefficients on education are negative, but insignificant, for both crop and livestock diversity.

Table A3.4

Correlates of Three Production Diversity Indicators

VARIABLES	(1) Crop Count	(2) Livestock Count	(3) Total Count
Farm area (ln)	0.420***	0.185**	0.605***
	(0.0869)	(0.0819)	(0.140)
Number of parcels	0.170**	0.0400	0.210**
	(0.0850)	(0.0683)	(0.106)
Wealth index	-0.0591	-0.150	-0.209
	(0.0919)	(0.119)	(0.167)
Female household head	0.0540	-0.385**	-0.331
	(0.158)	(0.186)	(0.243)
Age	0.0790**	0.0901**	0.169***
	(0.0368)	(0.0391)	(0.0569)
Age squared	-0.000849**	-0.000856**	-0.00170***
	(0.000379)	(0.000394)	(0.000571)
Education	-0.00708	0.00254	-0.00454
	(0.0203)	(0.0268)	(0.0354)
Household size	-0.0753*	0.0902*	0.0149
	(0.0399)	(0.0510)	(0.0690)
% Productive members (14 - 65 y)	-0.543*	0.196	-0.347
	(0.325)	(0.405)	(0.555)
Constant	2.195**	-0.332	1.863
	(0.882)	(0.975)	(1.500)
Village fixed effects	Y	Y	Y
Observations	286	286	286
R-squared	0.367	0.138	0.278

Note. Coefficient estimates from OLS. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

APPENDIX 8

Additional robustness checks include:

- Table 3.8: independent estimation of OLS, Poisson and log-transformed dependent variable models, and SUR joint estimation of long-transformed dependent variable models.
- Table 3.9: SUR joint estimation with OLS.
- Tables 3.10 and 3.12: SUR estimation where production diversity and dietary diversity are estimated jointly, and controlling for off-farm income.
- Tables 3.11 and 3.13: controlling for off-farm income.

As a final robustness check, all models were estimated with winsorized data to ensure that outliers are not driving any of the observed results.

CHAPTER 4
CONCLUSIONS

This thesis grew out of a research collaboration between Cornell University and CARE Perú, an NGO that advances a holistic mission encompassing sustainable development and poverty reduction, with programs that address climate change, agriculture, food security and nutrition objectives. Among other goals, CARE seeks to create programming that integrates multiple objectives across their different program areas. Additionally, as a member of Peru's Child Malnutrition Initiative, CARE Perú plays an active role in shaping child health and nutrition policy at the national level (Acosta and Haddad, 2014). However, efforts to promote public policies that integrate climate change, agriculture and nutrition are frequently challenged by a lack of collaboration between government agencies that support environmental quality, agricultural production and human health. Rigorous empirical research into the linkages among climate change, agriculture and nutrition can help to motivate cross-sectoral collaboration by revealing opportunities for national and regional policies that simultaneously address multiple shared objectives. Furthermore, academic research can help inform the design and delivery of programs that capitalize on synergies between climate adaptation, agricultural production and dietary quality. To address these needs, this thesis presents an empirical analysis of the linkages among agricultural production, climate adaptation, food security and nutrition outcomes based on original agricultural household survey data from 286 farming households in the Shullcas River Watershed, located in Peru's Andean region. The two primary objectives of this thesis are to: (1) evaluate the factors expected to influence farmer perceptions of climate change and their adoption of climate adaptive responses; and (2) identify relationships and pathways that link agriculture and food security at the household level, with consequences for nutritional outcomes. In this chapter, we summarize the main findings from the preceding chapters, and then discuss implications for integrated program design and policy development.

Agriculture is widely considered to be a key driver of rural economic development, particularly in developing countries where a majority of poor households pursue livelihoods that depend on farming. Given its inherent reliance on the natural environment, agriculture is also widely expected to be directly and severely impacted by long-term changes in temperature and precipitation. Poor farming households in developing countries are among those most vulnerable to climate risk. However, a variety of adaptation measures have the potential to greatly mitigate harmful effects of climate change on agriculture and food security. Understanding farmer perceptions of climate change and the factors that influence farmer adoption of adaptive responses is a critical step toward building programs and policies that enhance agricultural adaptation and build adaptive capacity at the household and village levels.

The overall results from Chapter 2 indicate that while farm households' perceptions of climate change are widespread, indeed universal, among survey respondents, the rate of conscious adaptation is low (around 15%). At the same time, however, we find that numerous households *do* employ one or more climate adaptive production practices – growing native potato varieties, planting trees, irrigating crops, or using soil and water conservation practices – although they may not consciously identify these practices as direct responses to climatic change. Our empirical results show that among the factors positively influencing the adoption of adaptive production practices are farm households' educational levels, *comunero* status, land ownership, and access to agricultural information from formal extension sources (NGO or government) and media sources.

Together these findings have several important implications. First, households select and adapt production practices in response to various stressors and opportunities. If climate change is not perceived to be the most serious threat to household well-being, then actions to address it may not be prioritized. Second, it follows that timely and relevant information is key to inform management priorities and decision-making. Better access to local climate information, including short-term weather forecasts, seasonal early warning systems and long-term climate projections may help to shift farmer perceptions of climate risk and motivate adaptive responses. Third, adaptive measures can offer net benefits independent of climate change. For example, soil and water conservation practices are expected to improve agricultural yields and production efficiency regardless of climatic stressors. Emphasizing the multiple benefits of any particular climate adaptation may thus help to enhance adoption. Fourth, adaptation may be more limited by exogenous constraints than by farmer perceptions of climate change. For instance, limited access to productive resources, including information, appears to constrain farmer uptake of certain adaptive responses despite widespread perceptions of climate change. Together, these four conclusions reflect the complexity of Andean farming systems and livelihood strategies, and highlight the importance of participatory research and development efforts. Together, nongovernmental organizations, research institutions and farming communities can inform a more responsive and nuanced climate policy by collaborating to identify resources, perceived threats, adaptive measures and barriers to adoption.

Although poor rural households in developing countries are widely dependent on agriculture for their livelihoods, increases in agricultural productivity do not necessarily lead to direct improvements in household dietary quality or individual nutritional status. There are multiple explanations for this apparent paradox: enhanced staple crop yields may increase the quantity, but not the quality, of household food consumption; intrahousehold food allocation patterns may not benefit those household members (e.g. children and women of childbearing age) whose nutritional needs are the greatest; and, market imperfections are widespread. Motivated by a growing international focus on food security and nutrition as key dimensions of rural development and human well-being, many recent studies have outlined specific pathways linking agriculture and nutrition. These studies also identify a critical need for empirical research to evaluate the factors that influence agriculture-nutrition linkages in order to inform the development of nutrition-sensitive agricultural practices and policies. The elaboration of these linkages and their effects is the main subject of Chapter 3.

As we have seen, the analysis reported in Chapter 3 employs two different dietary diversity indices to represent household dietary quality and nutritional status. As expected, the empirical results show that, holding all else equal, dietary diversity increases with wealth and farm size. These findings imply that dietary diversity is a normal good, and that it is directly related to agricultural production. Subsequently, the chapter explores the relative importance of two potential pathways linking household food production and food consumption. On the one hand, an *agricultural income pathway* is expected to enhance the nutritional quality of household diets if the revenue generated from household food production is used to purchase diverse and nutritious food items in the marketplace. On the other hand, a *production-consumption pathway* is expected when households incorporate increased production of nutrient-dense products into their farming systems for home consumption. Both pathways may coexist, yet we hypothesize that the agricultural income pathway is more important for households that report at least some crop sales, while the direct production-consumption pathway is more important for households that devote the entirety of their harvest to home consumption.

The results of Chapter 3 provide strong evidence of a direct production-consumption pathway linking agriculture and nutrition for farming households. This relationship holds regardless of whether or not a household sells any of its production in the marketplace. Accordingly, we conclude that the diversification of farm production is likely to improve household dietary diversity, which in turn is highly associated with nutritional quality, particularly for the poorest of households. The positive association between wealth and dietary diversity does suggest the presence of an income effect, but this does not appear to be driven by agricultural income. Given the relative proximity of villages in our study area to employment opportunities in the urban center of Huancayo, it is not surprising that income from off-farm livelihood activities appears to be an essential driver of dietary diversity and food security.

We do find weak evidence of an agricultural income pathway linking farm profit with dietary diversity, but only for households with crop sales. For the relatively small number of farms that operate primarily as commercial enterprises, policies that remove barriers to farm profitability are expected to enhance the income pathway linking household agricultural production with household nutrition. Such policies could include reducing transaction costs in markets for inputs, outputs or financial services, and further developing value chains that are inclusive of smallholders. However, for the vast majority of households with little or no crop sales, a focus on diversification of food production in tandem with support for off-farm livelihood activities is needed. In particular, diversification efforts should prioritize the incorporation of nutrient- and protein-dense plant and animal products into Andean farming systems that typically prioritize the production of starchy staple crops.

Overall, the results in this thesis suggest that agriculture holds promise for some, but not all, resource-poor farmers in Peru's Andean highlands. Investment in agriculture is essential to boost productivity and enhance adaptive capacity for farmers in the Andean region. Moreover, policy support for more diverse agricultural production has the potential to enhance food security and dietary quality, particularly among the poor. Farm diversification may also reduce climate vulnerability by spreading production risk across a broader portfolio of crop and livestock enterprises. However, policymakers can expect to encounter tradeoffs between efficiency and equity in the targeting of agricultural investments. Not all smallholder farmers have equal access to the natural resources, physical assets, financial services or human capital necessary to build profitable farms and successfully adapt to climate change. Investments that promote climate adaptation, enhance farm profitability or reduce production risk may offer greater economic returns if targeted to households with a relatively high productive capacity, whether that targeting occurs intentionally or through the self-selection of participants. However, such a strategy will come at a cost to equity if households facing the most severe constraints to production, or the greatest vulnerability to climate change, are excluded. This tradeoff highlights the importance of complementary social policies targeting the most vulnerable or asset-poor agricultural households, including strong social safety nets and support for transition to non-agricultural livelihoods, in order to achieve equity goals.

This thesis highlights several opportunities and considerations for NGOs pursuing integrated climate change, agriculture and nutrition programming at the village and farm levels. First, NGOs that work directly with farmers are uniquely suited to facilitate "bottom-up" processes through which individual farmers and agriculture-based communities identify their most pressing livelihood opportunities and threats, as well as their critical resources and needs, in order to establish an action plan for taking advantage of economic opportunities while reducing risks. Participatory research and community-based programs have the potential to generate new adaptation strategies that simultaneously address the multiple risks and opportunities that farmers face, and that identify and reduce barriers to adoption. By building on preexisting relationships with farmers and their communities, NGOs can diffuse new knowledge across those communities and beyond. Moreover, NGOs can help bridge the gap between farmers and government officials to ensure that regional and national policies complement and reinforce local efforts to build adaptive capacity.

Second, there is a need to translate regional and national meteorological data into accessible local information systems. Access to improved, site-specific weather forecasts, seasonal early warning systems and long-term climate projections can help farmers to make better management choices. However, in order to ensure the accessibility of such systems, farmer input into their design and functionality is essential. Again, NGOs that work closely with agricultural communities are particularly well positioned to support this effort by facilitating communication and collaboration between farmer groups, the National Meteorology and Hydrology Service (SENAMHI), and the Ministry of Agriculture and Irrigation (MINAGRI). Successful information systems must be timely, relevant and accessible to farmers. Our research suggests that radio, television and print media can be leveraged as information channels to influence farmer perceptions and behaviors. Media channels provide an efficient means to distribute timely and relevant information, yet only a small proportion (7.7%) of households in our study reported receiving agricultural information from media sources. Thus, the accessibility of information distributed through media channels, particularly to poor farmers in remote areas, merits additional attention.

Third, agricultural interventions that increase production diversity at the farm level may raise household dietary diversity, leading to better nutritional outcomes for individuals. NGO programs that leverage the direct linkage between the production and consumption of nutrient dense food items are likely to improve dietary quality and nutritional status, particularly among the poorest households who typically face more limited access to purchased foods. In particular, interventions to enhance the direct production-consumption pathway should prioritize the incorporation of nutrient-dense food products, such as fruits, vegetables, legumes and various sources of animal protein (eggs, meat and dairy), into farm production systems. As previously mentioned, the diversification of production is also expected to reduce climate vulnerability and enhance adaptive capacity at the farm level by distributing production risk across a more varied set of products. For NGOs interested in promoting farm diversification, it will be important to work closely with farmers and agricultural communities to identify specific food products and production practices that are compatible with existing livelihood activities and household dietary preferences, and that make efficient use of household labor.

Fourth, our analysis of the income pathway linking agriculture and nutrition suggests that efforts to reduce poverty and increase income levels among farming households should recognize and respond to their level of commercialization. On the one hand, expanding market linkages and increasing farm profitability could boost agricultural incomes and thereby stimulate dietary and nutritional benefits for those farming households that are firmly dedicated to commercial production. On the other hand, broadening access to, and enhancing the profitability of, off-farm livelihood opportunities is essential to ensuring dietary quality and food security for the majority of farming households in areas such as peri-urban Huancayo that report little or no agricultural income. Our research suggests that both agricultural and non-agricultural income pathways are compatible with farm diversification. Grouping households into typologies based on the degree of farm commercialization could help NGOs to develop interventions better targeted to the needs of specific groups.

Fifth, careful and intentional targeting of NGO interventions is needed to achieve the complex goals of integrated climate change, agriculture and nutrition projects. For instance, promoting farm diversification as a means to improve infant and young child nutrition is only viable if households with infants and young children participate. Our research suggests that agricultural extension and related projects led by NGOs or government entities tend to target households that are *comunero* members. However, this approach may exclude younger households that have not yet formally joined the *comunidad campesina* (peasant community), which are the very households likely to have infants or young children. Furthermore, although community meetings provide an efficient platform for NGO staff to share information with community members, these sessions may not be fully accessible to parents of young children. Just as government officials must consider the tradeoff between equity and efficiency when making agricultural policy and investment decisions, NGOs must consider the same tradeoff when making decisions about how to target their programs, recruit participants and share information with the intended audience. A heavy focus on working with *comunero* members may be an efficient strategy to diffuse information and promote adoption of new production practices, yet this targeting approach may exclude households with the highest degree of climate vulnerability.

In addition to implications for policy and programmatic development, this thesis reveals several knowledge gaps that are ripe for additional research. First, more detailed followup interviews with farmers could help to further elucidate why conscious adaptation rates are so low when climate change is so widely perceived (the discussion in Chapter 2 identifies some possible factors behind this gap). Research to identify behavioral barriers to adoption of conscious adaptation strategies would be particularly valuable, as well as research to understand why some farmers adopt or continue to use climate adaptive production practices for reasons other than climate change. A more nuanced understanding of how farmers perceive and respond to multiple livelihood stressors could help to inform the development of climate adaptive measures that offer multiple benefits and reduce barriers to adoption.

Future research efforts should also evaluate household time allocation patterns in relationship to the efficiency of various climate adaptive and nutrition sensitive production practices. The allocation of time to a range of livelihood activities by various members within a household has important implications for the effectiveness of agricultural interventions. If farm diversification or climate adaptation practices are intensive in household labor, then the opportunity cost of such practices may be significant, particularly when household members pursue other off-farm livelihood activities. The gendered nature of time allocation in Andean farming systems is a particularly important dimension to explore, as men are more likely to pursue off-farm income generating activities, while women are typically responsible for a significant percentage of household agricultural labor, as well as the bulk of domestic activities. One might expect a production practice that is intensive in male labor to have an opportunity cost related to foregone income from non-agricultural sources, while the opportunity cost of a production practice that is intensive in female labor may be measured in the reduced household capacity for meal preparation and childcare, with potential consequences for child and family nutrition. Given the nonseparable nature of household decision making regarding farm production practices, household labor allocation, off-farm livelihood activities, and household expenditure patterns, a more detailed study of time allocation by male and female household members could help to identify which climate adaptive and nutrition sensitive production practices best complement other livelihood activities and household objectives.

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APPENDIX 9

The household survey used in the data collection phase of this research is included in the following pages.

Cornell University & CARE Perú

Proyecto de Evaluación de los Cultivos Andinos para la Adaptación al Cambio Climático y la Seguridad Alimentaria

ESTA INFORMACIÓN ES ESTRICTAMENTE CONFIDENCIAL Y DEBE SER UTILIZADO SÓLO PARA LA INVESTIGACIÓN

Encuesta de Hogares: Parte 1 - Alimentación

Nombre del Encuestador:	**Código:**

Fecha & Hora de Visita

	FECHA	HORA		Duración de la Visita (minutos)	Estado de la Visita
	(dd/mm/aa)	Empezar (hh:mm)	Terminar (hh:mm)		
Primera Visita					
Segunda Visita					
Tercer Visita					

CODIGOS
1 = Completa
2 = Incompleta
3 = Rechazo
4 = Ausente
5 = Otro (especifique):

Control de Calidad

	Fecha (dd/mm/aa)	Nombre	¿Completa?
Primera Revisión			[ ] Si [ ] No
Segunda Revisión			[ ] Si [ ] No
Tercera Revisión			[ ] Si [ ] No

1. IDENTIFICACION DEL HOGAR

100 Número de Identificación del Hogar ____ ____ ____

101 Distrito
El Tambo……….…………………...……......01
Huancayo……………….………………..…....02

102 Comunidad
Acopalca……………..……………..……………01
Chamisería………………………..…..…………02
Cochas Chico………….…………...…………03
Cochas Grande……….……………..………...04
Cullpa Alta……….……..……………..…………05
Vilcacoto……………..……………..……………06

103 Dirección/Ubicación de la Casa

104 ¿Quién es el jefe o la jefa del hogar? (NOMBRE COMPLETO)

105 Sexo del Jefe / Jefa del hogar:
Masculino..01
Femenino..02

106 ¿Quién es la persona encargada de la alimentación para el hogar? (NOMBRE COMPLETO DE LA ENCUESTADA)

107 Sexo del Encuestada/o:
Masculino..01
Femenino..02

108 Relación de la Encuestada/o con el Jefe o la Jefa del hogar:
Jefe/a...01
Esposo/a..02
Madre/Padre...03
Hijo/a..04
Otro (cuál):________________________05

109 El hogar se clasifica como:
Comunero Activo................................01
Comunero Pasivo...............................02
No Comunero.....................................03

110 Notas / Observaciones

Formato de Consentimiento

Fecha: ___ /___ /______	No. del Hogar ___ ___ ___	Código de Encuestador: ___ ___ ___

Buenos días/tardes. Quisiéramos conversar con el jefe o la jefa del hogar. De acuerdo a lo conversado con la junta directiva de su comunidad, cumplimos con visitarlos para realizar una entrevista.

Mi nombre es _____________ y formo parte del equipo de encuestadores del Proyecto de Evaluación de los Cultivos Andinos para la Adaptación al Cambio Climático y la Seguridad Alimentaria, que es coordinado por la Universidad Cornell de los Estados Unidos y CARE Perú.

Estamos haciendo entrevistas para aprender cómo las prácticas agrícolas influyen sobre la alimentación y la nutrición, en especial para los niños menores de 5 años de edad y sus madres.

Queremos en esta oportunidad solicitar su participación en una entrevista para poder conocer sus opiniones sobre estos temas. Nos gustaría hacer una entrevista a la persona encargada de la alimentación de la familia. Las entrevista de alimentación tomará alrededor de media hora. En otro momento haremos una entrevista a la persona encargada de la producción agrícola. Asimismo, evaluaremos el estado nutricional de su niños(as) a través de la medición del peso y la talla.

Si estás hablando con la persona que puede responder a la encuesta, siga. Si no, preguntar:
¿Cuándo se puede encontrar a la persona encargada con la alimentación para realizar la entrevista?

Las entrevistas son totalmente voluntarias, si no acepta ser entrevistado, no hay ningún problema ni para Usted ni para nosotros. No es necesario contestar preguntas que Ud. no desea contestar, y se puede dejar de participar en cualquier momento. Nos gustaría que nos brinde todo su apoyo.

La información de las entrevistas se utilizará para hacer informes para los líderes de la comunidad y CARE Perú. No vamos a revelar los nombres de los participantes. Su privacidad será protegida y todo lo que diga será confidencial. La información que usted comparte es sólo para el equipo de evaluación de la Universidad Cornell y CARE Perú.

No hay ningún beneficio directo de participar, pero su información, junto con la de otros, nos ayudará a entender la manera de mejorar las medidas de adaptación al cambio climático para proteger la nutrición y seguridad alimentaria.

¿Usted tiene alguna pregunta acerca de la entrevista?

¿Desea participar?	Sí………	No………
¿Nos permite medir el peso y la talla de sus niños(as) menores de 5 años?	Sí………	No………

También, nos gustaría tomar fotos en algunos casos. Estas fotos se van a usar solamente para publicaciones, presentaciones y difusión del informe. Ni su nombre, ni el nombre de ningún miembro de la familia, se va a mostrar con la foto.

¿Usted está de acuerdo en que se le tome fotos?	Sí………	No………

Si usted tuviera alguna consulta durante la entrevista podemos atenderla. Le estamos entregando esta tarjeta con los nombres, direcciones y teléfonos que Usted necesitaría para contactarnos.

Declaro que he cumplido con el proceso de consentimiento, informando al Sr/Sra ______________________ siguiendo el texto anterior, de manera previa a la realización de la entrevista.

Nombre de Encuestador: ___________________________ Firma: ___________________________ Fecha: ______________

HORA DE EMPEZAR: ___ ___ : ___ ___

2. DEMOGRAFÍA DEL HOGAR

200. ¿Cuántas personas hay que viven en su **HOGAR**, por lo menos **6 MESES** del año, y que habitualmente comparten la comida familiar? __________

201. De estas ____ personas, ¿cuántos son niños menores de 5 años? __________

Para empezar, tengo unas preguntas sobre los miembros del hogar CON 5 AÑOS Y MÁS.

MIEMBROS DEL HOGAR CON 5 AÑOS CUMPLIDOS Y MÁS																	
CODIGO	**202** **¿CUÁLES SON LOS NOMBRES DE LOS MIEMBROS DE SU HOGAR?** **ORDEN:** ENTREVISTADA ESPOSO HIJOS CON 5 AÑOS Y MÁS OTROS PARIENTES NO PARIENTES	**203** **¿CUÁL ES LA RELACIÓN CON LA ENCUESTADA?** 1 ENCUESTADA 2 ESPOSO 3 HIJO / HIJA 4 YERNO / NUERA 5 NIETO / NIETA 6 PADRES / SUEGROS 7 HERMANO / A 8 OTROS PARIENTES 9 NO PARIENTES	**204** **SEXO** 1 M 2 F	**205** **EDAD** AÑOS	**206** **¿[*NOMBRE*] ESTABA AUSENTE DEL HOGAR DURANTE DOS SEMANAS O MÁS EN EL ÚLTIMO MES?** 1 SI 2 NO (>>> 208)	**EN CASO AFIRMATIVO:** **207** **¿POR QUÉ HA ESTADO AUSENTE DEL HOGAR?** 1 TRABAJO 2 ESTUDIOS 3 OTRO (CUÁL)	**208** **¿CUÁL ES EL NIVEL DE EDUCACIÓN ALCANZADO?** 1 SIN NIVEL 2 INICIAL 3 PRIMARIA INCOMPLETA 4 PRIMERIA COMPLETA 5 SECUNDARIA INCOMPLETA 6 SECUNDARIA COMPLETA 7 TECNICO INCOMPLETA 8 TECNICO COMPLETA 9 UNIVERSITARIO INCOMPLETA 10 UNIVERSITARIO COMPLETA	**209** **¿PARTICIPA EN LAS LABORES AGRÍCOLAS DE SUS CHACRAS O EN LA CRIANZA DE SUS ANIMALES?** 1 SI 2 NO	**210** **¿ALGÚN MIEMBRO DE SU HOGAR GANÓ DINERO POR [*TRABAJO*] EN LOS ÚLTIMOS 12 MESES? ¿QUIÉN?** 2 GANADERÍA O VENTA DE GANADO 3 VENTA DE LECHE, LÁCTEOS, LANA O MIEL 4 TRABAJO AGRÍCOLA JORNAL (PEÓN) 5 VENTA DE ARTESANÍAS 6 PROPIO NEGOCIO (tienda, restaurante, ventas, alquiler de carro) 7 OCUPACION INDEPENDIENTE (taxista, transportista, albañil, carpintería) 8 OCUPACION DEPENDIENTE (minería, fábrica, construcción, transporte) 9 OTRO TRABAJO (CUÁL)								**211** **¿CUÁL ES LA ACTIVIDAD PRINCIPAL PARA [*NOMBRE*]?** 1 LABORES AGRICOLAS DE LA CHACRA FAMILIAR 2 GANADERÍA O VENTA DE GANADO 3 VENTA DE LECHE, LÁCTEOS, LANA O MIEL 4 TRABAJO AGRÍCOLA JORNAL (PEÓN) 5 VENTA DE ARTESANÍAS 6 PROPIO NEGOCIO 7 OCUPACION INDEPENDIENTE 8 OCUPACION DEPENDIENTE 9 OTRO TRABAJO (CUÁL) 10 AMA DE CASA 11 ESTUDIANTE 12 JUBILADO / RETIRADO 13 OTRO NO TRABAJO (CUÁL)
01		1							2	3	4	5	6	7	8	9	
02									2	3	4	5	6	7	8	9	
03									2	3	4	5	6	7	8	9	
04									2	3	4	5	6	7	8	9	
05									2	3	4	5	6	7	8	9	
06									2	3	4	5	6	7	8	9	
07									2	3	4	5	6	7	8	9	
08									2	3	4	5	6	7	8	9	
09									2	3	4	5	6	7	8	9	
10									2	3	4	5	6	7	8	9	
11									2	3	4	5	6	7	8	9	
12									2	3	4	5	6	7	8	9	

212	**¿Cuánto tiempo hace que usted vive en la comunidad?**	# AÑOS:			
213	**¿Su hogar ha sembrado cultivos en la última campaña agrícola?**	SI........01 NO......02 (>>> 301)	**214. ¿Quién se carga de la producción agrícola del hogar?**	Persona #1:	Persona #2:

CODIGOS DE FALTA DE RESPUESTA: 97 = no saber/recordar; 99 = negarse a contestar

3. DEMOGRAFÍA DE LOS NIÑOS

[ ] Marque aquí si no hay ningún niño en el hogar que tiene menos de 5 años cumplidos (>>> 400)

NIÑOS DEL HOGAR CON 0 MESES - 4 AÑOS Y 11 MESES

CODIGO	301 ¿USTED TIENE NIÑOS MENORES DE 5 AÑOS? ¿QUIEN ES EL MÁS PEQUEÑO? ¿HAY OTRO NIÑO MENOR DE 5 AÑOS QUE VIVE EN EL HOGAR?	302 SEXO 1 = M 2 = F	303 ¿QUE EDAD TIENE [NOMBRE]? 00 = MENOR QUE 6 MESES 06 = ENTRE 6 MESES Y 1 AÑO	304 ¿[NOMBRE] TIENE DOCUMENTO CON LA FECHA DE NACIMIENTO? 1 DNI 2 PARTIDA DE NACIMIENTO 3 CUI (CODIGO UNICO DE IDENTIDAD) 4 CARNET DE CRECIMIENTO 5 LA MAMA 6 OTRO (CUÁL)	305 ¿EN QUE DÍA, MES Y AÑO NACIÓ [NOMBRE]?			306 ¿USTED ES LA [.........] DE [NOMBRE]? 1 MAMA 2 ABUELA 3 HERMANA MAYOR 4 MADRE ADOPTIVA 5 OTRO (CUÁL)	307 CÓDIGO DE LA MAMA (DE LA TABLA 2) 88 SI LA MAMA NO ES MIEMBRO DEL HOGAR	308 ¿LE DIO PECHO A [NOMBRE] ALGUNA VEZ? 1 SI 2 NO	309 ¿ALGUNA VEZ [NOMBRE] RECIBIÓ LECHE MATERNA DE OTRA MADRE? 1 SI 2 NO	310 ¿LE DIO PECHO A [NOMBRE] AYER DURANTE EL DÍA O POR LA NOCHE? 1 SI 2 NO	311 ¿AYER DURANTE EL DÍA O LA NOCHE [NOMBRE] TOMÓ ALGO EN BIBERÓN? 1 SI 2 NO
	NOMBRE & APELLIDO		AÑOS CUMPLIDOS		DD	MM	AA		CODIGO				
21													
22													
23													
24													

[ ] Marque aquí si no hay ningún niño en el hogar que tiene entre 6 meses y 59 meses cumplidos (>>> 400)

NIÑOS DEL HOGAR CON 6 MESES - 4 AÑOS Y 11 MESES

CODIGO	312 ¿CUÁNTOS MESES TENÍA [NOMBRE] CUANDO EMPEZÓ A ALIMENTARSE CON COMIDAS SOLIDAS O SEMI-SOLIDAS, QUE NO SEAN LÍQUIDOS? 88 = TODAVIA NO COME COMIDAS SOLIDAS (>>>314)	313 ¿AYER DURANTE EL DÍA O LA NOCHE, CUÁNTAS VECES COMIÓ [NOMBRE] COMIDAS SÓLIDAS O SEMI-SOLIDAS (QUE NO SEAN LÍQUIDOS)?	314 ¿[NOMBRE] HA TENIDO TOS EN LAS ÚLTIMAS DOS SEMANAS? 1 SI 2 NO	315 ¿[NOMBRE] HA TENIDO DIARREA EN LAS ÚLTIMAS DOS SEMANAS? 1 SI 2 NO	NIÑOS MENORES DE 3 AÑOS				NIÑOS DE 3 A 5 AÑOS		
						EN CASO AFIRMATIVO:				EN CASO AFIRMATIVO:	
					316 ¿[NOMBRE] HA IDO A CUNA MÁS EN LOS ÚLTIMOS 12 MESES? 1 SI (>>> 317) 2 NO (>>> SIGUIENTE NIÑO)	317 ¿[NOMBRE] ASISTIÓ A CUNA MÁS AYER? 1 SI (>>>318) 2 NO (>>> SIGUIENTE NIÑO)	318 EL DÍA DE AYER, ¿[NOMBRE] ASISTIÓ A CUNA MÁS POR TODO EL DÍA, DESDE LAS 8 DE LA MAÑANA HASTA LAS 4 DE LA TARDE? 1 SI (>>> SIGUIENTE NIÑO) 2 NO (>>>319)	319 EL DÍA DE AYER, ¿CUÁNDO ASISTIÓ [NOMBRE] A CUNA MÁS? 1 SÓLO POR LA MAÑANA 2 SÓLO POR LA TARDE 3 OTRO (CUÁL)	320 ¿[NOMBRE] HA IDO A UNA ESCUELA INICIAL, PRONOEI O JARDÍN DE NIÑOS EN LOS ÚLTIMOS 12 MESES? 1 SI (>>> 321) 2 NO (>>> SIGUIENTE NIÑO)	321 ¿[NOMBRE] ASISTIÓ A LA ESCUELA AYER? 1 SI (>>> 322) 2 NO (>>> SIGUIENTE NIÑO)	322 EL DÍA DE AYER, ¿[NOMBRE] RECIBIÓ COMIDA POR QALI WARMA EN LA ESCUELA? 1 SI 2 NO 97 NO SABE
	# DE MESES	# DE VECES									
21											
22											
23											
24											

CODIGOS DE FALTA DE RESPUESTA: 97 = no saber/recordar; 99 = negarse a contestar

4. ALIMENTACIÓN DEL NIÑO (6 MESES HASTA 59 MESES CUMPLIDOS)

[ ] Marque aquí si no hay ningún niño en el hogar que tiene entre 6 meses y 59 meses cumplidos (>>> 500)

400	Nombre y apellido del niño/niña:	Código:	# Meses:

Me gustaría preguntarle sobre la alimentación de [*NOMBRE*] ayer, desde el momento en que se despertó hasta que se fue a dormir.

¿Qué hizo [*NOMBRE*] al despertar ayer?
¿Que le dio en este momento?
¿Cómo lo preparó este alimento?
¿Le dio una comida especial?
¿Algo más?
¿Qué hizo [NOMBRE**] después de eso?**
¿Que le dio en este momento?

Como la entrevistada recuerda los alimentos, escribir '1' para cada grupo de alimentos que ha comido. Una vez que la entrevistada acabado recordando alimentos comido, lea cada grupo de alimentos donde '1' fue no informado y pide la pregunta: **¿[*NOMBRE*] comió [...] ayer?** Escribir '1' si la entrevistada dice si, y escribir '2' si no. Si el niño no come todavía, va a salir todos NO = 2.

Si la comida no figura en ninguno de los grupos alimenticos abajo, escriba la comida la casilla "OTROS ALIMENTOS." Si los alimentos se emplean en cantidades pequeñas como condimento, incluirlos bajo el grupo alimentos "CONDIMENTOS."

401 ALIMENTOS COMIDO EN **LAS ÚLTIMAS 24 HORAS** POR **[*NOMBRE*]** 1 SI 2 NO		**CODIGO**
F01	**ARROZ**	
F02	**MAIZ**	
F03	**PAN, FIDEOS, TRIGO, CEBADA O AVENA**	
F04	**QUINUA, KIWICHA O CAÑIHUA**	
F05	**PAPA NATIVA**	
F06	**OCA, OLLUCO, MASHUA O CUALQUIER OTRO TIPO DE TUBÉRCULO NATIVO**	
F07	**PAPA BLANCA O YUCA**	
F08	**TARWI (CHOCHO)**	
F09	**HABA, PALLAR, LENTEJA, FRIJOL, GARBANZO, ARVEJA, MANÍ U OTRO TIPO DE NUEZ O SEMILLA**	
F10	**ZAPALLO, ZANAHORIA O CAMOTE AMARILLO**	
F11	**VERDURAS DE HOJA VERDE OSCURO**	
F12	**CUALQUIER OTRO TIPO DE VERDURA**	
F13	**FRUTA DE ALTA VITAMINA A:** PAPAYA, MANGO, MARACUYÁ, LÚCUMA, AGUAJE, O ZAPOTE	
F14	**CUALQUIER OTRO TIPO DE FRUTA**	
F15	**CUALQUIER TIPO DE CARNE, AVE O VÍSCERAS**	
F16	**HUEVOS**	
F17	**PESCADO FRESCO, SECO, EN CONSERVA O MARISCOS**	
F18	**PRODUCTOS LÁCTEOS**	
F19	**ACEITE, GRASA, O COMIDAS COCIDOS EN ACEITE O GRASA**	
F20	**AZUCAR, MIEL, MERMELADA, CARAMELOS, PASTELES, TORTAS U OTROS PRODUCTOS AZUCARADOS**	
F21	**CONDIMENTOS:** AJÍ, ESPECIAS, HIERBAS, LIMÓN	
F22	**BEBIDAS:** MATE, AGUITAS, CAFÉ	
F23	**OTRA COMIDA:**	

CODIGOS DE FALTA DE RESPUESTA: 97 = no saber/recordar; 99 = negarse a contestar

5. LA VIVIENDA

500	¿Cuál es el **PRINCIPAL** tipo de combustible que usan en el hogar para cocinar sus alimentos? *MARQUE SOLO UNA RESPUESTA*	Leña	1
		Carbón	2
		Bosta	3
		Gas (>>>502)	4
		Otro (cuál): ________________________	5
501	SI EL HOGAR COCINA CON **LEÑA, CARBÓN O BOSTA:** ¿Tiene cocina mejorada?	Si	1
		No	2
502	¿El abastecimiento de agua en la vivienda procede de ... ? *LEA TODA LA LISTA Y MARQUE SOLO UNA RESPUESTA*	Cañería dentro de la casa	1
		Cañería fuera de la casa	2
		Pozo	3
		Canal	4
		Río	5
		Estanque	6
		Otro (cuál): ________________________	7
503	¿La fuente de agua que usan para beber está en la casa?	Si (>>> 505)	1
		No	2
504	**EN CASO NEGATIVO:** ¿Cuánto tiempo demora llegar a la principal fuente de agua para beber? *(viaje de ida)*	# MINUTOS:	
505	¿Trata el agua para beber?	Si, siempre	1
		Si, a veces	2
		No (>>> 507)	3
506	**EN CASO AFIRMATIVO:** ¿Qué haces **PRINCILPALMENTE** para tratar el agua para beber?	Hervir	1
		Clorar	2
		Otro (cuál): ________________________	3
507	¿El material predominante en las paredes exteriores de la vivienda es ..... ?	Piedra con barro	1
		Piedra con cemento	2
		Tapia	3
		Adobe	4
		Tapia o adobe con cemento	5
		Ladrillo	6
		Ladrillo con cemento	7
		Otro (cuál): ________________________	8
508	¿El material predominante en los pisos de la vivienda es ..... ?	Tierra	1
		Cemento	2
		Madera	3
		Otro (cuál): ________________________	4
509	¿El material predominante en los techos de la vivienda es ..... ?	Calamina	1
		Teja	2
		Paja	3
		Otro (cuál): ________________________	4
510	¿La vivienda tiene alumbrado eléctrico por red público?	Si	1
		No	2
511	¿Cuántos dormitorios hay en la vivienda? (ambientes que usan sólo para dormir)	# DORMITORIOS:	
512	¿Qué tipo de baño o servicio higiénico tiene la vivienda?	Conectado a red pública	1
		Pozo séptico	2
		Letrina	3
		Silo	4
		No hay	5
		Otro (cuál): ________________________	6

6. ACCESO A ALIMENTOS

601	¿En los **últimos 7 días**, algún miembro de su **HOGAR** ha comprado alimentos?	Si	1
		No (>>> 603)	2
602	**EN CASO AFIRMATIVO:** ¿De qué fuentes han comprado alimentos para el **HOGAR** en los **últimos s 7 días**? ***LEA TODA LA LISTA & MARCAR TODOS QUE APLIQUEN***	Bodega o tienda en la comunidad	1
		Mercado o feria local	2
		Mercado regional en Huancayo	3
		Pariente o vecino	4
		Otro (cuál): ________________________	5
603	¿Usted o algún miembro del **HOGAR** fue a un mercado fuera de la comunidad **AYER**?	Si	1
		No	2
604	¿Usted o alguien de su **HOGAR** compró y comió alguna comida fuera de la casa **AYER**?	Si	1
		No	2

605	¿Cuánto es su gasto **DIARIO** en alimentos que se compra cada día para el **HOGAR**? (frutas, verduras, pan, etc.)	**S/.**
606	¿Cuánto es su gasto **SEMANAL** en alimentos que se compra cada semana para el **HOGAR**? (carnes, etc.)	**S/.**
607	¿Cuánto es su gasto **MENSUAL** en alimentos que se compra cada mes para el **HOGAR**? (arroz, fideos, azúcar, aceite)	**S/.**

CODIGOS DE FALTA DE RESPUESTA: 97 = no saber/recordar; 99 = negarse a contestar

7. ALIMENTACIÓN DEL HOGAR

Me gustaría hacer unas preguntas acerca de la alimentación del **HOGAR**.
En este caso, **HOGAR** quiere decir **TODAS LAS PERSONAS** que viven en la casa y habitualmente comparten la comida familiar.

700 ¿Algún **MIEMBRO DE SU HOGAR** ha comido [.........] en **LOS ÚLTIMOS SIETE DÍAS?** 1 SI 2 NO		**COD**	**EN CASO AFIRMATIVO:** **701** ¿En cuántos **DÍAS** de **LOS ÚLTIMOS SIETE DÍAS** han comido este alimento alguien del **HOGAR**? NUMERO DE DÍAS (ENTRE 1 - 7)	**702** ¿Algún miembro del **HOGAR** comió este alimento **AYER**? 1 SI 2 NO	**703** **¿Cuáles de estos alimentos son comprados?** 1 Comprado **¿Cómo obtiene [........] su hogar?** 2 Producción propia 3 Intercambio (trueque) 4 Regalo o prestado 5 Ayuda alimentaria (Vaso de Leche, Qali Warma, etc.) 6 Otro (cuál)
F01	**ARROZ**				
F02	**MAIZ**				
F03	**PAN, FIDEOS, TRIGO, CEBADA O AVENA**				
F04	**QUINUA, KIWICHA O CAÑIHUA**				
F05	**PAPA NATIVA**				
F06	**OCA, OLLUCO, MASHUA** **O CUALQUIER OTRO TIPO DE TUBÉRCULO NATIVO**				
F07	**PAPA BLANCA O YUCA**				
F08	**TARWI (CHOCHO)**				
F09	**HABA, PALLAR, LENTEJA, FRIJOL, GARBANZO, ARVEJA, MANÍ U OTRO TIPO DE NUEZ O SEMILLA**				
F10	**ZAPALLO, ZANAHORIA, CAMOTE AMARILLO**				
F11	**VERDURAS DE HOJA VERDE OSCURO:** espinaca, acelga, hoja de quinua, hojas de nabo, etc.				
F12	**CUALQUIER OTRO TIPO DE VERDURA:** lechuga, apio, nabo, rabanito, cebolla, betarraga, vainita, coles, repollo, coliflor, palta				
F13	**PAPAYA, MANGO, MARACUYA, LÚCUMA, AGUAJE, O ZAPOTE**				
F14	**CUALQUIER OTRO TIPO DE FRUTA:** plátano, manzana, naranja, mandarina, pina, etc.				
F15	**CUALQUIER TIPO DE CARNE, AVE O VÍSCERAS**				
F16	**HUEVOS**				
F17	**PESCADO FRESCO, SECO, EN CONSERVA O MARISCOS**				
F18	**PRODUCTOS LÁCTEOS**				
F19	**ACEITE, GRASA, O COMIDAS COCIDOS EN ACEITE O GRASA**				
F20	**AZUCAR, MIEL, MERMELADA, CARAMELOS, PASTELES, TORTAS U OTROS PRODUCTOS AZUCARADOS**				

F21	**CONDIMENTOS:** AJÍ, ESPECIAS, HIERBAS, LIMÓN				
F22	**BEBIDAS:** MATE, AGUITAS, CAFÉ				

CODIGOS DE FALTA DE RESPUESTA: 97 = no saber/recordar; 99 = negarse a contestar

8. PRODUCCIÓN DE LECHE

800	¿Su hogar tiene vacas **EN PRODUCCIÓN**? (producción de leche)		Si......................................01 No....................................02
801	**SI TIENE VACAS EN PRODUCCIÓN:**	¿Cuántos litros de leche producen al día?	LITROS:
802		De estos ____ litros, ¿cuántos se dedican para la venta?	LITROS:
803		¿Cuántos litros se dedican para la elaboración de subproductos (queso, yogur)?	LITROS:
804		¿Cuántos litros consumen en la familia?	LITROS:
805		¿Cuántas vacas tiene **EN PRODUCCIÓN** en este momento?	# VACAS:

9. PRODUCCIÓN DE VERDURAS Y HORTALIZAS

900	¿El hogar ha sembrado cualquiera verdura o hortaliza para el consumo del hogar en el último año?				Si............01 No...........02 (>>> 1000)
901	¿Qué verduras o hortalizas sembró en la última campaña agrícola?	Lechuga............01 Acelga...............02 Espinaca...........03 Col....................04 Brócoli..............05	Coliflor..............06 Zanahoria..........07 Betarraga..........08 Nabo.................09 Rábano..............10	Caigua...............11 Zapallo...............12 Cebolla................13 Cebolla china.......14 Ajo........................15	Perejil...................16 Culantro...............17 Huacatay..............18 Manzanilla..........19 Otra (cuál)..........20
902	¿Qué es el área de tierra sembrada con estas verduras y hortalizas?		AREA:	Hectáreas...01 Yugadas...02 Metros Cuadrados....................................03 Otro (cuál)__________________________04	

10. GANADERIA

1000 **¿Su hogar cría animales actualmente?**	SI..............01 NO............02 (>>> 1100)

	1001 **¿SU HOGAR CRÍA [................]?** 1 SI 2 NO	**COD.**	**EN CASO AFIRMATIVO:** **1002** **¿CUÁNTOS [...] TIENE EL HOGAR?**
G01	VACAS / VAQUILLAS		
G02	TOROS / TORETES		
G03	OVEJAS		
G04	ALPACAS		
G05	LLAMAS		
G06	BURROS		
G07	CABALLOS / YEGUAS		
G08	CERDOS		
G09	POLLOS, GALLINAS, PATOS, PAVOS		
G10	CUYES		
G11	COLMENAS DE ABEJAS		
G12	OTRO (CUÁL):		

11. BIENES & INGRESOS

	1100 **¿ES USTED O CUALQUIER MIEMBRO DEL HOGAR PROPIETARIO DE [...]?** 1 SI 2 NO	**COD.**	**EN CASO AFIRMATIVO:** **1101** **¿CUÁNTOS [...] TIENE EL HOGAR?**
B01	RADIO		
B02	TELEVISION		
B03	CELULAR		
B04	TELEFONO FIJO		
B05	COMPUTADORA		
B06	REFRIGERADORA		
B07	LICUADORA		
B08	MAQUINA DE COSER O TEJER		
B09	BICICLETA		
B10	MOTOCICLETA		
B11	AUTO, CAMIONETA		
B12	TRACTOR		

1103	¿Algún miembro de su hogar recibe dinero de alguien que vive y trabaja fuera de la comunidad (remesas)?	SI...01 NO...02	
1104	¿Cuál es la **primera** fuente de ingresos para el hogar?	VENTA DE CULTIVOS AGRÍCOLAS (CULTIVOS PROPIOS)................................01 VENTA DE GANADO (GANADERÍA)...02 VENTA DE LECHE, LÁCTEOS, LANA O MIEL...03 TRABAJO AGRÍCOLA JORNAL (PEÓN) ....04 VENTA DE ARTESANÍAS..05 PROPIO NEGOCIO...06 OCUPACION INDEPENDIENTE...07 OCUPACION DEPENDIENTE...08 OTRO TRABAJO (CUÁL)______________________________________09 PROGRAMAS SOCIALES (JUNTOS, Pensión 65, etc.) ....10 REMESAS DE ALGUIEN QUE VIVE Y TRABAJA FUERA DE LA COMUNIDAD....11 PENSIÓN...12 OTRO NO TRABAJO (CUÁL)_________________________________13	
1105	¿Cuál es la **segunda** fuente de ingresos para el hogar?	CODIGO DE LA FUENTE (DE PREGUNTA 1104):	NO HAY SEGUNDA FUENTE...14

12. SALUD & PROGRAMAS SOCIALES

1200	¿En general, cómo está su salud?	Muy buen estado de salud	1
		Más o menos bien	2
		Más o menos mal	3
		Mal estado de salud	4
1201	¿Usted tiene seguro de salud?	SIS	1
		ESSALUD	2
		Otro (cuál): ____________________	3
		No tiene	4
1202	¿Cuánto tiempo se tarda en llegar desde el hogar hasta el **Puesto de Salud**?	MINUTOS:	
1203	¿Cuánto tiempo se tarda en llegar desde el hogar hasta el cuidado diurno **Cuna Más**?	MINUTOS:	
1204	¿Algún miembro de su **hogar** recibe alimentos del programa Vaso de Leche **actualmente**?	Si	1
		No	2
1205	¿Algún miembro de su **hogar** recibe ingresos por el programa JUNTOS **actualmente**?	Si	1
		No	2
1206	¿Algún miembro de su **hogar** recibe ingresos por el programa Pensión 65 **actualmente**?	Si	1
		No	2

Gracias por su participación. Esto termina la entrevista sobre la alimentación y el consumo del hogar.

HORA DE TERMINAR: ____ ____ : ____ ____

¿Usted tiene alguna pregunta o consulta para CARE Perú?

NOTAS / OBSERVACIONES:

CALENDARIO PARA CALCULAR LA EDAD MENSUAL - HOY ES EL ____ DE OCTUBRE 2015

1) SI EL NIÑO NACIÓ **EN ESTE DÍA DEL MES O ANTES**, BUSCA EL AÑO Y MES DE NACIMIENTO ABAJO Y ESCRIBE LA EDAD MENSUAL DE LA TABLA.

2) SI EL NIÑO NACIÓ **DESPUÉS DE ESTE DÍA DEL MES**, BUSCA EL AÑO Y MES DE NACIMIENTO Y SUSTRAIGA 1 DE LA EDAD MENSUAL DE LA TABLA

2010		**2011**		**2012**		**2013**		**2014**		**2015**	
Enero	69	Enero	57	Enero	45	Enero	33	Enero	21	Enero	09
Febrero	68	Febrero	56	Febrero	44	Febrero	32	Febrero	20	Febrero	08
Marzo	67	Marzo	55	Marzo	43	Marzo	31	Marzo	19	Marzo	07
Abril	66	Abril	54	Abril	42	Abril	30	Abril	18	Abril	06
Mayo	65	Mayo	53	Mayo	41	Mayo	29	Mayo	17	Mayo	05
Junio	64	Junio	52	Junio	40	Junio	28	Junio	16	Junio	04
Julio	63	Julio	51	Julio	39	Julio	27	Julio	15	Julio	03
Agosto	62	Agosto	50	Agosto	38	Agosto	26	Agosto	14	Agosto	02
Septiembre	61	Septiembre	49	Septiembre	37	Septiembre	25	Septiembre	13	Septiembre	01
Octubre	60	Octubre	48	Octubre	36	Octubre	24	Octubre	12	Octubre	00
Noviembre	59	Noviembre	47	Noviembre	35	Noviembre	23	Noviembre	11	Noviembre	
Diciembre	58	Diciembre	46	Diciembre	34	Diciembre	22	Diciembre	10	Diciembre	

Proyecto de Evaluación de los Cultivos Andinos para
la Adaptación al Cambio Climático y la Seguridad Alimentaria

ESTA INFORMACIÓN ES ESTRICTAMENTE CONFIDENCIAL Y DEBE SER UTILIZADO SÓLO PARA LA INVESTIGACIÓN

Encuesta de Hogares: Parte 2 - Producción

Nombre del Encuestador:	**Código:**

Fecha & Hora de Visita

	FECHA	HORA		Duración de la Visita (minutos)	Estado de la Visita
	(dd/mm/aa)	Empezar (hh:mm)	Terminar (hh:mm)		
Primera Visita					
Segunda Visita					
Tercer Visita					

CODIGOS
1 = Completa
2 = Incompleta
3 = Rechazo
4 = Ausente
5 = Otro (especifique):

Control de Calidad

	FECHA (dd/mm/aa)	NOMBRE	¿Completa?
Primera Revisión			[ ] Si [ ] No
Segunda Revisión			[ ] Si [ ] No
Entrada de Datos			[ ] Si [ ] No

13. IDENTIFICACION DEL HOGAR

1300 Número de Identificación del Hogar ____ ____ ____	
1301 Distrito	El Tambo……………………………………..01 Huancayo……………………………………..02
1302 Comunidad	Acopalca……………………………………01 Chamisería…………………………………02 Cochas Chico………………………………03 Cochas Grande……………………………04 Cullpa Alta…………………………………05 Vilcacoto……………………………………06
1303 Dirección/Ubicación de la casa	
1304 Nombre Completo del Encuestado(a)	**1305 Sexo del Encuestado(a):** Masculino.................01 Femenino.................02 **1306 Código del Encuestado(a):**
1307 Relación del Encuestado(a) con el Jefe o la Jefa del hogar: Jefe/a...01 Esposo/a..02 Madre/Padre..03 Hijo/a...04 Otro (cuál):______________________________05	**1308 El hogar se clasifica como:** Comunero Activo...............................01 Comunero Pasivo...............................02 No Comunero....................................03
1309 Notas	

HORA DE EMPEZAR: ___ ___ : ___ ___

14. PARTICIPACION SOCIAL

1400	¿Algún miembro de su hogar ha participado en organizaciones campesinas en **los últimos tres años**? Por ejemplo, la comunidad campesina, gobierno local, grupo de agricultores, grupo de mujeres, comité de vaso de leche, u otros.	Si...............01 No..............02 (>>> 1408)

1401 **TIPO DE AGRUPACIÓN** 1. COMUNIDAD CAMPESINA 2. JUNTA DIRECTIVA COMUNAL 3. ASOCIACION DE AGRICULTORES 4. GRUPO DE MUJERES 5. CODECO - Comité de Desarrollo Comunal 6. JASS - Junta Administradora del Servicio de Saneamiento 7. DIRECTIVO DEL COMITE DE RIEGO 8. DIRECTIVO DEL COMITE DE VASO DE LECHE 9. OTRO (CUÁL)		**1402** **NOMBRE DEL PARTICIPANTE** CODIGO VIENE DE LA TABLA 2 DE LA PARTE ALIMENTACIÓN PONER EL CODIGO DESPUES DE TERMINAR CON LA ENTREVISTA		**1403** **LA FUNCIÓN MÁS IMPORTANTE DEL GRUPO:** 1. DESAROLLO COMUNAL 2. GESTION DE PROYECTOS 3. MERCADEO DE PRODUCCION 3. ACCESO A INSUMOS 4. PRODUCCION DE SEMILLA 5. CONSERVACION DE AGUA Y SUELOS 6. OTRO (CUÁL)	**1404** **AÑO QUE SE UNIÓ AL GRUPO**	**1405** **ROL EN EL GRUPO** 1. DIRECTIVO 2. MIEMBRO ORDINARIO	**1406** **¿TODAVÍA ES MIEMBRO ACTUALMENTE?** 1 SI 2 NO	**1407** **¿CON QUÉ FREQUENCIA PARTICIPA EN LAS ACTIVIDADES DE LA AGRUPACIÓN?** 1 DIARIA 2 SEMANAL 3 QUINCENAL 4 MENSUAL 5 TRIMESTRAL 6 SEMESTRAL 7 ANUAL 8 NO ACTIVO 9 OTRO (CUÁL)
	CODIGO DEL GRUPO	NOMBRE	COD		AÑO (AAAA)			
01								
02								
03								
04								
05								
06								
07								
08								

1408	¿Cuántas personas hay **en su comunidad** que usted puede confiar para apoyo en momentos críticos de necesidad? Por ejemplo, para apoyar cuando un miembro del hogar está enfermo, o para prestar dinero.	# PARIENTES:	# NO PARIENTES:
1409	¿Cuántas personas hay **fuera de su comunidad** que usted puede confiar para apoyo en momentos críticos de necesidad? Por ejemplo, para apoyar cuando un miembro del hogar está enfermo, o para prestar dinero.	# PARIENTES:	# NO PARIENTES:

15. PARCELAS AGRÍCOLAS

Ahora queremos hablar sobre las parcelas que le pertenecen al hogar. Le pediremos primero que nos dé estimaciones de las áreas y distancia.

1500	¿Cuántas parcelas tiene el hogar en total, incluyendo cultivos, pastos naturales y terrenos en descanso?	# PARCELAS:

CODIGO DE PARCELA	**1501** **NOMBRE DE LA PARCELA O LUGAR (O PARAJE)**	**1502** **¿QUÉ AREA TIENE LA PARCELA?** UNIDADES: 1. HECTARIAS 2. YUGADAS 3. METROS CUADRADOS 4. OTRO (CUÁL):		**1503** **¿CUÁNTO TIEMPO SE TARDA EN LLEGAR A LA PARCELA DESDE LA CASA?**	**1504** **¿EL RÉGIMEN DE TENENCIA DE ESTA PARCELA ES ... ?** 1. PROPIETARIO CON TITULO 2. PROPIETARIO SIN TITULO 3. PRESTADO 4. ARENDATARIO 5. AL PARTIR 6. COMUNAL PARTIDO 7. COMUNAL COLECTIVO 8. OTRO (CUÁL):	**1505** **¿HACE CUÁNTO TIEMPO QUE COMENZÓ USTED A USAR ESTA PARCELA?**	**1506** **¿LA PARCELA ESTÁ UBICADA EN ZONA:** 1. BAJA? 2. MEDIA? 3. ALTA?	**1507** **¿LA PARCELA ES DE PENDIENTE:** 1. PLANA? 2. POCA? 3. MUCHA? 4. LADERA?	**1508** **¿LA CALIDAD DEL SUELO EN ESTA PARCELA ES:** 1. BUENA? 2. REGULAR? 3. POBRE?	**1509** **¿ESTA PARCELA:** 1. TIENE RIEGO? 2. ES DE SECANO? (>>> 1511)	**1510** **¿TIENE RIEGO:** 1. POR INUNDACIÓN? 2. POR ASPERCIÓN? 3. OTRO? (CUÁL):	**1511** **USO DE LA PARCELA EN LOS ÚLTIMOS 12 MESES:** 1. CULTIVOS 2. PASTOS NATURALES 3. DESCANSO 4. OTRO (CUÁL)	**SOLO PARA USO = CULTIVOS** **1512** **¿CUÁNTAS CAMPAÑAS AGRÍCOLAS REALIZÓ EN ESTA PARCELA EN LOS ÚLTIMOS 12 MESES?**
	NOMBRE / LUGAR	AREA	UNIDAD	MINUTOS		# DE AÑOS							# CAMPAÑAS
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													

CODIGOS DE FALTA DE RESPUESTA: 97 = no saber/recordar; 99 = negarse a contestar

16. PRODUCCIÓN POR PARCELA

Seguimos conversando sobre el uso que le dan a las parcelas del hogar, durante **la última campaña agrícola, de 2014 a 2015.**

1601 **¿QUÉ CULTIVOS SEMBRÓ EN CADA PARCELA EN EL ÚLTIMO AÑO?** Registre las parcelas en que sembró cultivos el último año (código de parcela de la tabla en página 3) y los cultivos de cada parcela. Si las parcelas son cultivadas con más que un cultivo, escribe un cultivo por fila, repitiendo el código y el nombre de la parcela. Si siembran **Papa** en una de las parcelas, por favor distinguir entre **Papa Nativa (1)** y **Papa Blanca (2)**.					**1602** **¿QUÉ CANTIDAD DE SEMILLA SEMBRÓ EN CADA PARCELA?** UNIDADES 1. KILOS 2. ARROBAS 3. OTRO (CUÁL)		**1603** **¿CUÁNTO COSECHÓ EN ESTOS CULTIVOS EN LA CAMPAÑA DE 2014 - 2015?** UNIDADES 1. SACOS DE 50 KG 2. SACOS DE 70 KG 3. SACOS DE 80 KG 4. SACOS DE 100 KG 5. SACOS DE _____ KG 6. KILOS 7. ARROBAS 8. TONELADAS 9. MANTADAS 10. OTRO (CUÁL)		**1604** **EN RELACIÓN A LA CANTIDAD TOTAL,** **¿CUÁNTO DESTINÓ A LA VENTA?** **¿A PAGOS EN ESPECIAS O INTERCAMBIO?** **¿A SEMILLA PARA SIEMBRA EN LA PRÓXIMA CAMPAÑA?** **¿A CONSUMO DEL HOGAR HASTA LA FECHA?** **¿A ALIMENTO PARA SUS ANIMALES?**					**SI HABIA VENTA** **1605** **TIPO PRINCIPAL DE MERCADO** 1. CHACRA 2. MERCADO LOCAL 3. MERCADO REGIONAL (HUANCAYO) 4. EMPRESA 5. OTRO (CUÁL)	**1606** **¿CUÁNTO GANÓ POR SU VENTA EN CADA PARCELA EN EL ÚLTIMO AÑO?**
									VENTA	**PAGO O INTERCAMBIO**	**ALIMENTO ANIMALES**	**SEMILLA**	**AUTO-CONSUMO**		
CODIGO PARCELA	NOMBRE PARCELA	CODIGO CULTIVO	NOMBRE CULTIVO	CAMPAÑA (1 o 2)	CANTIDAD	UNIDAD	CANTIDAD	UNIDAD	KILOS	KILOS	KILOS	KILOS	KILOS		SOLES

CODIGO DEL CULTIVO:

1 PAPA NATIVA	4 MASHUA	7 MAIZ	10 OTRO GRANO (CUÁL)	13 VAINITAS	16 OTRA HORTALIZA (CUÁL)
2 PAPA BLANCA MEJORADA	5 OCA	8 QUINUA	11 HABA	14 ARVEJAS	17 FRUTA (CUÁL)
3 OLLUCO	6 OTRO TUBÉRCULO (CUÁL)	9 CEBADA	12 TARWI	15 ALCACHOFA	18 PASTO CULTIVADO (CUÁL)

17. VARIEDADES DE PAPA

1700	¿El hogar cultivó **PAPA** en los últimos 12 meses? (Responder de acuerdo a la lista de cultivos en la página anterior).	Si...............01 No..............02 (>>> 1800)
1701	¿Cuántas variedades de **PAPA NATIVA** sembró en la última campaña agrícola?	# VARIEDADES:
1702	¿Cuántas variedades de **PAPA BLANCA MEJORADA** sembró en la última campaña agrícola?	# VARIEDADES:

Seguimos hablando de unas variedades de papa, a ver si usted ha oído de estas variedades y si las ha sembrado alguna vez.

						EN CASO AFIRMATIVO			**EN CASO AFIRMATIVO: EN LA ÚLTIMA CAMPAÑA**			
1703 **ALGUNOS VARIEDADES DE PAPA**		**1704** **¿CONOCE A ESTA VARIEDAD?** 1 SI 2 NO (>>> SIGUIENTE VARIEDAD)	**1705** **¿CÓMO HA OÍDO DE ESTA VARIEDAD?** **FUENTE DE INFORMACIÓN** 1 MINISTERIO DE AGRICULTURA 2 ASOCIACION DE AGRICULTORES 3 CARE PERU 4 OTRA ONG 5 INSTITUCION DE INVESTIGACION (CIP, INIA) 6 OTRO PARIENTE AGRICULTOR 7 OTRO VECINO AGRICULTOR 8 TIENDA AGROPECUARIO 9 RADIO, PERIODICO O TV 10 OTRO (CUÁL)	**1706** **¿EN QUÉ AÑO CONOCIÓ A LA VARIEDAD?**	**1707** **¿ALGUNA VEZ LA SEMBRÓ?** 1 SI 2 NO (>>> SIGUIENTE VARIEDAD)	**1708** **PRIMER AÑO QUE SEMBRÓ**	**1709** **FUENTE DE SEMILLA EN EL PRIMER AÑO QUE SEMBRÓ** 1 MINISTERIO DE AGRICULTURA 2 ASOCIACION DE AGRICULTORES 3 CARE PERU 4 OTRA ONG 5 INSTITUCION DE INVESTIGACION 6 OTRO PARIENTE AGRICULTOR 7 OTRO VECINO AGRICULTOR 8 TIENDA AGROPECUARIO 9 OTRO (CUÁL)	**1710** **¿LO SEMBRÓ EN LA ÚLTIMA CAMPAÑA AGRÍCOLA?** 1 SI 2 NO (>>> SIGUIENTE VARIEDAD)	**1711** **CANTIDAD DE SEMILLA QUÉ SEMBRÓ**	**1712** **TOTAL COSECHA POR CADA VARIEDAD** UNIDADES 1. SACOS DE 50 KG 2. SACOS DE 70 KG 3. SACOS DE 80 KG 4. SACOS DE 100 KG 5. SACOS DE ___ KG 6. KILOS 7. ARROBAS 8. TONELADAS 9. OTRO (CUÁL)		**1713** **¿CUÁL FUE EL USO PRINCIPAL DE LA COSECHA DE CADA VARIEDAD?** 1 VENTA (>>> 1513) 2 PAGOS O INTERCAMBIO 3 SEMILLA 4 AUTO-CONSUMO DEL HOGAR 5 OTRO USO (CUÁL)
				AÑO (AAAA)		AÑO (AAAA)			KILOS	CANTIDAD	UNIDAD	
P01	ALCARRAZA											
P02	AMARILLA DEL CENTRO											
P03	CALLHUAY											
P04	CAMOTILLO											
P05	CCECORANI											
P06	CHAULINA											
P07	HUAYRO											
P08	LEONA											
P09	PERUANITA											
P10	SUMACC SONCCO											
P11	QEQURANI											
P12	WINQU											
P13	YANA PUMAPA MAKIN											
P14	YAWAR WAYKU											
P15	PERRICHOLI											
P16	YUNGAY											

CODIGOS DE FALTA DE RESPUESTA: 97 = no saber/recordar; 99 = negarse a contestar

18. PRÁCTICAS DE MANEJO DE AGUA Y SUELOS

1800 PRÁCTICAS		1801 ¿USTED HA OÍDO DE ESTA PRÁCTICA? 1 SI 2 NO (>>> SIGUIENTE PRACTICA)	1802 ¿CÓMO HA OÍDO DE ESTA PRÁCTICA? 1 MINISTERIO DE AGRICULTURA 2 ASOCIACION DE AGRICULTORES 3 CARE PERU 4 OTRA ONG 5 INSTITUCIONES DE INVESTIGACION (CIP, INIA) 6 OTRO PARIENTE AGRICULTOR 7 OTRO VECINO AGRICULTOR 8 RADIO, PERIODICO O TV 9 OTRO (CUÁL)	1803 ¿EN QUÉ AÑO CONOCIÓ LA PRÁCTICA?	1804 ¿ALGUNA VEZ REALIZÓ ESTA PRÁCTICA EN ALGUNO DE SUS PARCELAS? 1 SI 2 NO (>>> SIGUIENTE PRACTICA)	1805 ¿REALIZÓ ESTA PRÁCTICA EN EL ÚLTIMO AÑO EN ALGUNO DE SUS PARCELAS? 1 SI 2 NO (>>> SIGUIENTE PRACTICA)	EN CASO AFIRMATIVO: EN LA ÚLTIMA CAMPAÑA						
							1806 PARCELA(S) EN QUE USÓ LA PRÁCTICA. CÓDIGO DE LA TABLA EN PÁGINA 3					1807 ¿USA ESTA PRACICA POR TODA LA PARCELA O EN UNA PARTE DE LA PARCELA? 1. EN TOTAL (>>> SIGUIENTE PRACTICA) 2. UNA PARTE	1808 ¿EN QUE PARTE DE SU PARCELA SE USA ESTA PRACTICA? 1. 0 - 25% 2. 26% - 50% 3. 51% - 75% 4. 76% - 99%
				AÑO (AAAA)			COD #1	COD #2	COD #3	COD #4	COD #5		
1	CURVAS A NIVEL												
2	TERRAZAS DE BANCO												
3	BARRERAS VIVAS												
4	BARRERA DE PIEDRA												
5	TERRAZAS DE FORMACION LENTA												
6	ZANJAS DE INFILTRACION (A NIVEL)												
7	CERCAS VIVAS												
8	SISTEMAS AGROFORESTALES												
9	SISTEMAS DE POLICULTIVOS												
10	ZANJAS DE DRENAJE												
11	MANEJO DE ROTACIÓN DE CULTIVOS												
12	MANEJO INTEGRADO DE PLAGAS												
13	ABONOS ORGANICOS												
14	OTRA (CUÁL):												

ARBOLES

1809	¿El hogar ha plantado arboles en **los últimos 5 años**?	Si................01 No...............02 (>>> 1600)

En caso afirmativo...

1810 ¿QUÉ TIPOS DE ARBOLES HA PLANTADO EN LOS ÚLTIMOS 3 AÑOS?		1811 PARA CADA TIPO, ¿CUÁNTOS HA PLANTADO EN LOS ÚLTIMOS 3 AÑOS?	1812 LOS OBJETIVOS PRINCIPALES DE PLANTAR CADA UNO DE LOS TIPOS DE ARBOLES SON: 1 LEÑA 2 CONSUMO HUMANO 3 FORRAJE PARA ANIMALES 4 SOMBRA 5 CONSERVAR / MEJORAR SUELOS 6 CONTRA EL VIENTO 7 REDUCIR DAÑOS POR HELADAS 8 MADERA / CONSTRUCCIÓN 9 OTRO (CUÁL)	
#	NOMBRE DEL ARBOL	# ARBOLES	PRIMERO	SEGUNDO
A01				
A02				
A03				
A04				

CODIGOS DE FALTA DE RESPUESTA: 97 = no saber/recordar; 99 = negarse a contestar

19. GASTOS DE PRODUCCIÓN Y JORNALES

Me gustaría hacerle algunas preguntas que se refieren a los costos de producción para los 3 cultivos más importantes de su hogar.

1901 **¿Cuáles eran los tres cultivos más importantes para su hogar?** **PARA CADA CULTIVO: ¿Cuánto gastó durante los últimos 12 meses en [............]?**		**#1**	**#2**	**#3**
		NOMBRE DEL CULTIVO	NOMBRE DEL CULTIVO	NOMBRE DEL CULTIVO
		CÓDIGO DEL CULTIVO	CÓDIGO DEL CULTIVO	CÓDIGO DEL CULTIVO
		GASTO EN SOLES / AÑO	**GASTO EN SOLES / AÑO**	**GASTO EN SOLES / AÑO**
C01	Semillas y plantones			
C02	Fertilizar (incluso fertilizantes, abonos)			
C03	Manejo de plagas (incluso pesticidas)			
C04	Compra de sacos, canastas, cajones u otros envases			
C05	Transportes			
C06	Otros gastos (alquiler de tractores, mantenimiento, máquina de riego, pago de peones, etc.)			

1902 **PARA CADA CULTIVO: ¿Cuántos jornales se ocupó para cada actividad en los últimos 12 meses?** **Por favor, incluir mano de obra familiar, mano de obra comunal y mano de obra pagado (peones) en estos estimaciones de jornales anuales.**		**#1**	**#2**	**#3**
		CÓDIGO DEL CULTIVO	CÓDIGO DEL CULTIVO	CÓDIGO DEL CULTIVO
		JORNALES / AÑO	**JORNALES / AÑO**	**JORNALES / AÑO**
J01	Preparación de la tierra			
J02	Siembra			
J03	Fertilizar / Abonar			
J04	Deshierba			
J05	Manejo de riego			
J06	Manejo de plagas			
J07	Actividades de conservación de agua o de suelos (cualquiera de las prácticas de la página anterior)			
J08	Cosecha			
J09	Transporte			
J10	Venta			

1903 **PARA CADA CULTIVO: ¿Aproximadamente qué parte del mano de obra para este cultivo es ... ?**		**#1**	**#2**	**#3**
		CÓDIGO DEL CULTIVO	CÓDIGO DEL CULTIVO	CÓDIGO DEL CULTIVO
		%	**%**	**%**
M01	Mano de obra familiar			
M02	Mano de obra comunal			
M03	Mano de obra pagado (peones)			
TOTAL		**100%**	**100%**	**100%**

1904	¿Aproximadamente qué parte de su ingreso familiar provino de la producción y venta de sus propios **CULTIVOS AGRICOLAS** en el último año?	**PORCENTAJE (%):**

20. CAMBIOS DEL CLIMA

2000	¿Cuántos años hace que usted ha vivido en la comunidad?	# AÑOS:

[ ] Marcar aquí si es menos de 10 años (>>> 2200)

Ahora me gustaría hacer unas preguntas acerca de qué cambios usted ha observado en el clima **DURANTE LOS ÚLTIMOS 10 a 15 AÑOS.** No hay respuestas buenas ni malas a estas preguntas, nos gustaría justo conocer sus opiniones y perspectivas sobre si o no ha cambiado el clima aquí en esta zona **DURANTE LOS ÚLTIMOS 10 a 15 AÑOS**.

2001 **¿HA HABIDO CAMBIOS EN [.................] DURANTE LOS ÚLTIMOS 15 AÑOS?** EN CASO AFIRMATIVO: **¿EN QUÉ MANERA HA CAMBIADO?**			**CODIGO**	**EN CASO AFIRMATIVO:** **2002** ¿HA HABIDO UN IMPACTO NEGATIVO **EN SU PRODUCCIÓN AGRÍCOLA** POR ESTE CAMBIO? 1 SI 2 NO (>>> SIGUIENTE CAMBIO)	**2003** ¿QUÉ TAN GRANDE HA SIDO EL IMPACTO? 1 POCO 2 MODERADO 3 GRANDE
CC01	¿Ha habido cambios en **el inicio de la temporada de lluvias** durante los últimos 10 a 15 años?	1 SI - se adelanto 2 SI - se retraso 3 NO - se mantiene igual (>>> CC02)			
CC02	¿Ha habido cambios en **la duración de la temporada de lluvias** durante los últimos 10 a 15 años?	1 SI - dura más tiempo 2 SI - dura menos tiempo 3 NO - se mantiene igual (>>> CC03)			
CC03	¿Ha habido cambios en l**a intensidad de las lluvias** durante los últimos 10 a 15 años?	1 SI - es más fuerte 2 SI - es menos fuerte 3 NO - se mantiene igual (>>> CC04)			
CC04	¿Ha habido cambios en **el número de días secos (sin lluvia) durante la temporada de lluvias** durante los últimos 10 a 15 años?	1 SI - aumentó el número de días secos 2 SI - disminuyó el número de días secos 3 NO - se mantiene igual (>>> CC05)			
CC05	¿Ha habido cambios en **la duración de la temporada de heladas** durante los últimos 10 a 15 años?	1 SI - aumentó 2 SI - disminuyó 3 NO - se mantiene igual (>>> CC06)			
CC06	¿Ha habido cambios **en el número de heladas fuera de la temporada de heladas** durante los últimos 10 a 15 años?	1 SI - aumentó 2 SI - disminuyó 3 NO - se mantiene igual (>>> CC07)			
CC07	¿Ha habido **nuevas plagas o enfermedades en los cultivos** durante los últimos 10 a 15 años?	1 SI 3 NO (>>> CC08)			
CC08	¿Ha habido cambios en **la frecuencia de las sequías** durante los últimos 10 a 15 años?	1 SI - aumentó 2 SI - disminuyó 3 NO - se mantiene igual (>>> CC09)			
CC09	¿Ha habido cambios en **la frecuencia de las inundaciones** durante los últimos 10 a 15 años?	1 SI - aumentó 2 SI - disminuyó 3 NO - se mantiene igual (>>> CC10)			
CC10	¿Ha habido cambios en **el nivel de agua de los ríos** durante los últimos 10 a 15 años?	1 SI - aumentó el nivel 2 SI - disminuyó el nivel 3 NO - se mantiene igual (>>> CC11)			
CC11	¿Ha habido cambios en **la intensidad del viento** durante los últimos 10 a 15 años?	1 SI - aumentó 2 SI - disminuyó 3 NO - se mantiene igual (>>> CC12)			
CC12	¿Ha habido **otro cambio climático en esta zona** durante los últimos 10 a 15 años? (cuál):	1 SI 3 NO (>>> 2100)			

21. RESPUESTAS A LOS CAMBIOS CLIMATICOS

2100	¿Su hogar ha hecho algún cambio en sus prácticas de producción para responder a estos cambios en el clima que usted ha observado?	Si...............01 No..............02 (>>> 2200)

EN CASO AFIRMATIVO:
¿En qué manera ha cambiado sus prácticas de producción para responder a estos cambios en el clima (DAR EJEMPLOS) que usted ha observado?

2101. RESPUESTA #1	**CAMBIOS EN:** LOS CULTIVOS QUE SIEMBRA EL HOGAR..................01 LAS VARIEDADES QUE SIEMBRA EL HOGAR.............02 LA SUPERFICIE CULTIVADA..03 EL MOMENTO DE SEMBRAR...04 PRÁCTICAS DE RIEGO...05 PRÁCTICAS DE QUEMAR...06 PRÁCTICAS DE MANEJAR LOS SUELOS......................07 PRÁCTICAS DE MANEJAR EL AGUA.............................08 PRÁCTICAS DE FERTILIZACIÓN....................................09 PRÁCTICAS DE MANEJO DE PLAGAS..........................10 ARBOLES / SISTEMAS AGROFORESTALES.................11 OTRO (CUÁL)..12
2102. RESPUESTA #2	**CAMBIOS EN:** LOS CULTIVOS QUE SIEMBRA EL HOGAR..................01 LAS VARIEDADES QUE SIEMBRA EL HOGAR.............02 LA SUPERFICIE CULTIVADA..03 EL MOMENTO DE SEMBRAR...04 PRÁCTICAS DE RIEGO...05 PRÁCTICAS DE QUEMAR...06 PRÁCTICAS DE MANEJAR LOS SUELOS......................07 PRÁCTICAS DE MANEJAR EL AGUA.............................08 PRÁCTICAS DE FERTILIZACIÓN....................................09 PRÁCTICAS DE MANEJO DE PLAGAS..........................10 ARBOLES / SISTEMAS AGROFORESTALES.................11 OTRO (CUÁL)..12
2103. RESPUESTA #3	**CAMBIOS EN:** LOS CULTIVOS QUE SIEMBRA EL HOGAR..................01 LAS VARIEDADES QUE SIEMBRA EL HOGAR.............02 LA SUPERFICIE CULTIVADA..03 EL MOMENTO DE SEMBRAR...04 PRÁCTICAS DE RIEGO...05 PRÁCTICAS DE QUEMAR...06 PRÁCTICAS DE MANEJAR LOS SUELOS......................07 PRÁCTICAS DE MANEJAR EL AGUA.............................08 PRÁCTICAS DE FERTILIZACIÓN....................................09 PRÁCTICAS DE MANEJO DE PLAGAS..........................10 ARBOLES / SISTEMAS AGROFORESTALES.................11 OTRO (CUÁL)..12
2103. RESPUESTA #4	**CAMBIOS EN:** LOS CULTIVOS QUE SIEMBRA EL HOGAR..................01 LAS VARIEDADES QUE SIEMBRA EL HOGAR.............02 LA SUPERFICIE CULTIVADA..03 EL MOMENTO DE SEMBRAR...04 PRÁCTICAS DE RIEGO...05 PRÁCTICAS DE QUEMAR...06 PRÁCTICAS DE MANEJAR LOS SUELOS......................07 PRÁCTICAS DE MANEJAR EL AGUA.............................08 PRÁCTICAS DE FERTILIZACIÓN....................................09 PRÁCTICAS DE MANEJO DE PLAGAS..........................10 ARBOLES / SISTEMAS AGROFORESTALES.................11 OTRO (CUÁL)..12
2103. RESPUESTA #5	**CAMBIOS EN:** LOS CULTIVOS QUE SIEMBRA EL HOGAR..................01 LAS VARIEDADES QUE SIEMBRA EL HOGAR.............02 LA SUPERFICIE CULTIVADA..03 EL MOMENTO DE SEMBRAR...04 PRÁCTICAS DE RIEGO...05 PRÁCTICAS DE QUEMAR...06 PRÁCTICAS DE MANEJAR LOS SUELOS......................07 PRÁCTICAS DE MANEJAR EL AGUA.............................08 PRÁCTICAS DE FERTILIZACIÓN....................................09 PRÁCTICAS DE MANEJO DE PLAGAS..........................10 ARBOLES / SISTEMAS AGROFORESTALES.................11 OTRO (CUÁL)..12

22. EXTENSIÓN AGRÍCOLA

Ahora me gustaría preguntarle de la información que recibe su hogar para sus actividades agrícolas, y de la participación de su hogar en capacitaciones agrícolas.

2201 ¿ALGÚN MIEMBRO DE SU HOGAR RECIBIÓ INFORMACION O CONSEJOS PARA SUS ACTIVIDADES AGRÍCOLAS DE CUALQUIERA DE LAS SIGUIENTES FUENTES EN LOS ÚLTIMOS 12 MESES? *LEER TODA LA LISTA* 1 SI 2 NO		COD	EN CASO AFIRMATIVO: 2202 ¿CUÁNTES VECES VISITÓ SU CHACRA O SU HOGAR ALGUIEN DE [*FUENTE*] EN LOS ÚLTIMOS 12 MESES?
F01	MINISTERIO DE AGRICULTURA		
F02	ASOCIACION DE AGRICULTORES		
F03	REPRESENTANTES DE TIENDAS AGROPECUARIOS		
F04	CARE PERÚ		
F05	OTRA ONG		
F06	ORGANIZACION DE INVESTIGACIÓN (CIP, INEI)		
F07	SENAMHI (Servicio Nacional de Meteorología e Hidrología del Perú)		
F08	OTRO PARIENTE AGRICULTOR		
F09	OTRO VECINO AGRICULTOR		
F10	RADIO, PERIODICO O TV		
F11	OTRA FUENTE (CUAL):		

2203 ¿ ALGÚN MIENBRO DE SU HOGAR HA PARTICIPADO EN ACTIVIDADES DE CAPACITACIÓN? POR EJEMPLO… *LEER TODA LA LISTA* 1 SI 2 NO		COD	EN CASO AFIRMATIVO: 2204 ¿CUÁNTES VECES HA PARTICIPADO EN ESTA ACTIVIDAD EN LOS ÚLTIMOS 12 MESES?
E01	TALLERES DE CAPACITACIÓN		
E02	PASANTIA (VIAJE DE INTERCAMBIO DE EXPERIENCIAS FUERA DE LA COMUNIDAD)		
E03	VISITAS DE INTERCAMBIO DE EXPERIENCIAS (LOCAL)		
E04	ESCUELAS DE CAMPO		
E05	CURSO DE EXTENSION AGRICOLA (EN UNA INSTITUCIÓN FORMAL)		
E06	OTRA ACTIVIDAD (CUÁL):		

23. PARTICIPACIÓN EN PROYECTOS ONG

2300 ¿ALGUN MIEMBRO DE SU HOGAR HA PARTICIPADO EN UN PROYECTO AGRÍCOLA CON CARE PERÚ? SI.......................01 NO.....................02 (>>> 2302)	2301 ¿CUÁL FUE EL ASPECTO MÁS IMPORTANTE DE ESTE PROYECTO?	2302 ¿ALGUN MIEMBRO DE SU HOGAR HA PARTICIPADO EN UN PROYECTO AGRÍCOLA CON OTRA ONG U ORGANIZACION DE INVESTIGACION? SI.....................................01 NO...................................02 (>>> FIN)	2303 ¿CÓMO SE LLAMA LA ORGANIZACIÓN? 2304 ¿CUÁL FUE EL ASPECTO MÁS IMPORTANTE DE ESTE PROYECTO?

Gracias por su participación. Esto termina la entrevista sobre la producción agrícola.

HORA DE TERMINAR: ____ ____ : ____ ____

¿Usted tiene alguna pregunta o consulta para CARE Perú?

NOTAS / OBSERVACIONES: